Limit Order Trading and Information Asymmetry: Empirical Evidence about the Evolution of Liquidity on an Order Driven Market

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ABSTRACT

This paper is concerned with investigating the order placement behaviour of different types of traders on the ASX. We find strong evidence of informed traders' use of limit orders, as well as insights into the evolution of liquidity over a trading day. The greatest increase of informed traders' use of limit orders is during the last two hours of trading before closing. We also find evidence that the information value processed by informed traders make them more successful in their use of limit orders. This impact is considered substantial as in our sample the volume of limit orders from informed traders under-weighs that of the other traders by a large amount. The order strategy of liquidity traders displays a relatively flat "U" shaped pattern with more limit orders being used at the opening. It is also found that the pattern of the informed traders' order placement shows an increase in the use of market orders. This is a result of the unique trading mechanism which entails a closing call auction as applied on the ASX. Traders that have information about the true value of stocks act on it through the use of market orders before the continuous trading platform closes.

Keywords: Evolution of liquidity; Informed trader; Limit order; Information asymmetry

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1. Introduction

It has been the general view that informed traders always prefer market orders (Easley and O'Hara (1987), Rock (1990), Glosten (1994) and Seppi (1997)). However, some recent studies found evidence that informed traders also use limit orders, sometimes even more than market orders (Berber and Caglio (2005), Bloomfield, et al. (2005), Foucault (1999)). The present study complements the existing findings from approaches made within both the theoretical and experimental market frameworks to the issue, by investigating the order behaviour of both informed and liquidity traders on an order driven market with a unique identification of trader types.

We find strong evidence of informed traders' use of limit orders. In our sample out of the total number of orders submitted by informed traders, 64% are limit orders. In the light of the experimental study of Bloomfield, et al. (2005), there is evidence of the evolution of liquidity. In general, our results suggest that a trader's order placement strategy changes through the trading day, exhibiting an inverted concave curve shape with the hour of the day. First of all, with respect to the informed traders' use of limit orders, we find that the greatest increase of their use of limit orders is during the last two hours before closing, verifying their role as quasi market makers by providing liquidity in the afternoon, as proposed in previous experimental framework. We also provide empirical evidence that the information value processed by informed traders make them more successful in their limit order strategy as they are not exposed to non-execution risk and adverse selection risk as are other traders. A 1% increase in the limit

order submission rate from informed traders leads to 0.89% increase in the total execution of limit orders, but this increase is only 0.11% if the limit order submission is from the other traders. This impact may be considered to be very substantial as in our sample the volume of limit orders from informed traders under-weighs that of the other traders by a large amount.

Secondly, the order strategy of liquidity traders displays a relatively flat "U" shaped pattern with more limit orders being used at the opening. This is consistent with the theory and findings on other markets that these traders try to protect themselves from trading with informed traders who are taking advantage of the over night arrival of information through trading aggressively at the opening. There is however no evidence of them switching to more market orders as the close of trading approaches since the presence of a close call auction makes them believe that non-execution risk will be arguably smaller.

Thirdly, the pattern of the informed traders' orders shows an increase in the use of market orders. This is at odds with Bloomfield et al.'s (2005) experimental study, but is probably a result from the unique trading mechanism which entails the presence of a closing call auction as applied on the ASX. Traders that have information about the true value of stocks would like to act on it quickly through the use of market orders before the continuous trading platform closes at 16:00:00. We found that 70% of the time the close price is different from the last trade price at 16:00:00 when the continuous trading platform shuts by more than 5% in the sample. If the close price obtained from the closing call auction at 16:15:00 is assumed to reflect all information on the market, then our finding may be an indication that the surge in the use of market orders is a

manifestation of (informed) traders' proactive exploitation of their informational advantage before prices adjust.

The theoretical models of Easley and O'Hara (1987), Rock (1990), Glosten (1994) and Seppi (1997) assume that informed traders will always prefer market orders over limit orders. Given the time-decaying nature of "private information", informed traders should aim to exploit their informational advantage as quickly as possible in order to maximise profits before prices adjust. The non-execution risk of limit orders is thought to make them inappropriate in this context. Handa and Schwartz (1996) note that limit order trading is costly and risky because the trader who places a buy (sell) limit order writes a free put (call) option which can be exploited by other traders.[2]

In contrast, submitting a market order guarantees effectively immediate execution, but requires the trader to pay the cost of immediacy. In a less restrictive position, Harris (1998) predicts that the use of market orders by informed traders will be influenced by their opinion on the persistence of their informational advantage and by transaction costs. For example, if they possess relatively longer-lived information and a wider spread may this may outweigh non-execution risk and encourage informed traders to prefer a combination of both market and limit orders.

Recently, Beber and Caglio (2005) consider order strategies prior to positive earnings announcements. Despite the increase in information asymmetry, informed traders are found to prefer submitting buy orders well below the bid price. This seemingly passive strategy may be an attempt to hide and therefore maintain their informational advantage

[2] In general, traders using limit order encounter risk of adverse selection and non-execution risk.

in order to trade at better prices, at least to some extent. However, with the time-decaying nature of information, the strategy may need be modified over the course of the trading period. Bloomfield et al. (2005) use an experimental market setting to investigate the evolution of liquidity in an electronic limit order market. Bloomfield et al. (2005) form the view market price is more likely to differ from true value by a greater extent early on. Informed traders will use market orders to "pick-off" differences during this "window of opportunity" if miss-pricing outweighs the cost of immediacy. As prices systematically update during the trading period an informed trader can instead place limit orders around the true value to earn the bid-ask spread. Bloomfield et al. (2005) point out that, in comparison to liquidity traders, informed traders face a far lower risk of adverse selection, the informational advantage of informed traders allows them to price limit orders more aggressively, thereby reducing non-execution risk. It is found that in total informed traders submit more limit orders than liquidity traders, and the difference is statistically significant. The current paper contributes to the literature by empirically testing this justification for informed traders' use of limit orders and shows how the private information they possess may lead to a successful limit order strategy.

Anand et al. (2005) empirically investigate the evolution of liquidity in the manner of Bloomfield et al. (2005) from a sample of NYSE stocks. They find that institutional (informed) traders price their limit orders more aggressively than retail (liquidity) traders. Over the course of trading day, institutional traders appear to initially use market orders to exploit their informational advantage to earn larger profits, and then to supply liquidity to earn the bid-ask spread. However, with the existence of a market maker, the trading mechanism of NYSE is distinctively different from that specified in

Bloomfield et al. (2005). The parallel that can be drawn from the conclusions of the two studies is therefore limited. In the present paper, we investigate the evolution of liquidity from a typical electronic limit order market, and provide empirical evidence to match the hypotheses from the experimental study of Bloomfield et al. (2005).

The behaviour of liquidity traders has gained a higher degree of consensus in the literature. Liquidity traders are generally assumed to be uninformed and to focus on reaching a transaction target by (or before) the end of the trading period[3]. They subsequently behave in a manner consistent with Harris (1998), by submitting relatively fewer limit orders as the trading period progresses. Harris (1998) predicts that early in the trading period, liquidity traders will typically prefer to use limit orders to avoid paying the cost of immediacy. As the close of trading approaches, non-execution risk increases, so they will switch to a greater proportion of market orders to ensure that their targets are achieved before the market closes.

Another important caveat recognised by Anand et al. (2005) is that the classification of institutional traders as "informed" is not completely precise. Institutions will also trade for liquidity purposes and the motivation behind different institutional trades is difficult to identify. In the light of the empirical evidence in Barclay and Warner (1993) and Chakravarty (2001) supporting the "stealth-trading" hypothesis for medium sized institutional trades, it is also important to consider the trade size (number of shares). In the present paper, the classification of informed and liquidity traders is performed in the context of a method that takes into account both the traders classification provided by the ASX and order sizes.

[3] See (Harris (1998), Lo and Sapp (2005), Bloomfield (2005).

The remainder of the paper is arranged as follows. Next section provides a description of the sources of the data. Section 3 explains the hypotheses and develops the research methodology adopted, whilst Section 4 presents and discusses the results and finally, Section 5 concludes.

2. Data

We use order and trade information for all stocks in the S&P/ASX 50 Index for the time period January 2 to June 30 2003.[4] Data is sourced from the Securities Industry Research Centre of Asia-Pacific (SIRCA). The top 50 stocks account for more than 65% of the market capitalization on the ASX. The data-set contains every order placed and trade executed, and records the following information: stock code, date, time, price, volume, trade indicator (buy/sell), order type (market or limit order), order status (enter, amend/cancel or trade) and broker type (institutional, retail or other)[5]. Amongst others, the paper of Lee et al. (2004) provides recent evidence that institutions are more likely to be informed traders, whilst individuals are more likely to be liquidity (or noise) traders.

To conduct our analysis we divide the trading period into twelve intervals of 30 minutes from opening 10:10:00 to closing 16:00:00. The first ten minutes of the trading period from 10am are omitted to avoid any potential confounding effects due to the staggered market opening procedure in practice on the ASX. The use of time intervals reflects an

[4] According to the ASX website, "The S&P/ASX 50 index comprises the 50 largest stocks by market capitalisation in Australia. The constituent companies represent the biggest national and multi-national publicly listed companies in the Australian equity market. The S&P/ASX 50 index places an emphasis on liquidity and investability."

[5] The classification of broker type is prescribed by the ASX.

attempt to consider changing information asymmetry, adverse selection risk, non-execution risk and volatility over the course of the trading period.

3. The classification of informed and liquidity traders

The classification of the informed and liquidity traders is a potentially confounding factor when comparing the proportions of limit orders submitted over time by these traders. [6] Although in general the institutional traders are thought of as being informed traders, they sometimes also trade for liquidity reasons, or for other sophisticated reasons which are hard to identify. We first obtain information on the broker classification from the ASX, which classify brokers into three groups, institutional, retail, and other, and we then use trade sizes as a second criteria for identifying the informed traders. Barclay and Warner (1993) claim that the most effective way for informed traders to exploit their informational advantage to maximise profits is to use (multiple) medium sized trades. Large sized trades are more likely to be treated as significant by the market, resulting in prices quickly adjusting, while small sized trades are undesirable in terms of the total transaction costs incurred. Chakravarty (2001) finds that medium sized trades are associated with 79% of cumulative stock price changes, and almost all of this change is driven by institutional trades. Anand et al. (2005) divide their sample into small, medium and large sized initiating trades. It is found that medium sized institutional trades in general have greater cumulative impact on price than other orders, an indication that they are most likely to be informed.

[6] It could also be argued that not all retail trades are motivated by liquidity. However, the number of trades where an individual trader actually has an informational advantage over the market / institutional traders is likely to be very low.

All market orders and marketable limit orders in our sample are divided into small (0-1,999 shares), medium (2,000-49,999 shares), and large (50,000 + shares) according to the sizes. This classification of trade sizes takes into account the scale of the Australian Stock Exchange relative to that of the NYSE. Our classification is consistent with Barclay and Warner (1993) in that the small size group accounts for around 50% of all trades in the sample. We then compute the cumulative stock returns and the results are presented in Table 1.

It is apparent in Table 1 that the medium sized orders account for cumulative price changes to the greatest degree, especially in Panel B where the market largely moves in one direction. Small orders account for 53% of total transactions, but only explain 1% of price changes through time. Large orders are not frequently used, but they also accounts for only 8% of price changes. The majority of cumulative price changes are from medium-sized orders, which are attributed to 90% of cumulative price changes, and this is disproportional to the percentage of the number of orders or trading volume in the size group. In other words, this impact cannot be explained by differences in volume or number of orders. This finding is consistent with the stealth trading hypothesis, indicating that on the ASX medium sized orders are more informative than orders of the other sizes.

We therefore incorporate this finding in our classification of informed and liquidity traders. To do so, we further filter institutional traders' orders by sizes, and define informed traders as those who are 'institutional', and submit orders in medium sizes. The liquidity traders are those classified as 'retail' by the ASX. The 'other' traders are those classified as 'other' by the ASX, plus those institutional traders who submit small

or large orders. The descriptive statistics for these three groups of traders as classified are presented in Table 2 below.

Insert Table 2 about here

4. Results

4.1 The order behaviour of informed vs. liquidity traders – an overview

In this section we examine whether the order submission strategies of informed and liquidity traders are different. The number of limit and market orders entered by informed and liquidity traders over the course of a trading day is depicted in Figures 1 and 2, respectively.

Insert Figures 1 and 2 about here

First of all, the widely documented 'U' shaped pattern in trading volume and volatility in prior studies is also evident in Figures 1 and 2 to an obvious degree. For example, Figure 1 shows the order submissions of informed traders exhibit a sharper rise and fall compared to those of liquidity traders as depicted in Figure 2. It is not surprising that for both types of traders we see that the use of limit orders dominates traders' order placing strategy. The effect of limit order submissions and executions are discussed in the next section.

In contrast, the pattern showing in Figure 2 is more of a flat pattern of liquidity traders' order placement through out the trading day. Nevertheless, there is a clear sign that liquidity traders submit significantly more limit orders at the start of the trading day,

with a much large number of limit orders submitted to the market within the first trading hour relative to the rest of the day. This submission strategy of liquidity traders is also observed on exchanges featuring other market mechanisms[7] and is consistent with the theoretical proposition that liquidity traders try to avoid losing from trading with informed traders who would be aggressively exploiting any private information that arrived overnight before the prices are updated as trading progresses through the day.

On the other hand, a close comparison of the market orders used by the informed and liquidity traders reveals something intriguing. For presentation purposes, we place the curves of the number of market orders submitted by both types of traders together in Figure 3. The number of market orders used by liquidity traders, following a flat "U" shaped pattern, starts off at a slightly higher level than that of informed traders until late afternoon when it is totally surpassed. On the surface, this observation is at odds with the prediction of the evolution of liquidity whereby the informed traders tend to use market orders less often towards the end of the trading day when their information value has decreased. It is however quite intelligible when considered in association with the unique trading system prevailing on the ASX. According to Figure 3, the biggest surge in the use of market orders occurs in the last half hour leading to the Pre Closing Single Price Auction (CSPA) stage between 16:00 and 16:10, during which time only limit orders are allowed as there is no execution of orders. The closing price is then obtained at around 16:10 through a call auction process. As the time gets near to the closing call auction stage, informed traders knowing the true value of the stock would want to take advantage of the last opportunity by submitting market orders. For

[7] Harris (1998) and Bloomfield et al. (2005).

example, if an investor believes the stock price is currently priced lower than its true price even after accounting for the bid/ask spread, he/she would like to take a position in this stock quickly before a higher closing price is determined by an update to reflect all the information that is obtained through the call auction. If the under-pricing is substantial enough, the investor can even put in a selling order at the Pre Closing stage to make an immediate profit from it. Another possible reason for an increase in the use of market orders by informed traders is that they (usually institutional traders) have obligations to their companies or clients and are taking their last opportunity to lock in the profit or to meet the targe portfolio value.

By contrast, the liquidity traders that do not have private information keep a fairly consistent pattern in their submission of market orders. Moreover, they do not necessarily switch to more market orders towards the closing time because they perceive that the closing auction mechanism starting from 16:00 arguably reduces non-execution risk.[8]

4.2 The evolution of liquidity –an examination of the limit orders

This section explores the issue of the evolution of liquidity through an investigation of submitted and executed limit orders by all types of traders. In particular, the main focus is an attempt to find evidence of the quasi-market maker role played by informed traders with their use of limit orders. First of all, Figure 4 compares the use of limit orders by informed and liquidity traders in terms of the number of limit orders submitted by these traders. A more concave curve of informed traders shows that they

[8] The experimental market in Bloomfield et al. (2005) did not incorporate a closing auction.

are more strategic in their use of limit orders relative to liquidity traders. It is now clear how the role of liquidity provision has changed though the day. Starting off with more orders placed by liquidity traders, followed by a stage of low levels of participation before and around lunch time, then eventually the informed traders become the main liquidity provider to the market in the late afternoon before closing. The increasing amount of limit orders submitted in the afternoon leading up to the closing time suggests that informed traders gradually start to take up a role as quasi-market makers at the later stages of a trading day. However, Figure 4 does not make it clear whether informed traders necessarily use more limit orders in the afternoon compared to in the morning, as a feature of the evolution of liquidity. This issue is tested directly in the following regression analyses.

At this stage of analysis an OLS regression is employed to formally investigate whether informed traders' limit order placement is related to the time of the day. We hope to find evidence that they use more limit orders in the afternoon than during the first half of the day. The dependent variable is the informed traders' limit order submission rate. To compute it we first aggregate the data from order level to 30-minute intervals[9] for each stock in the sample. Then the dependent variable, *Inf*, the submission rate of informed traders, is computed as the number of limit orders submitted by informed traders on the sum of their limit plus market orders in each interval. *Inf* is calculated separately for selling and buying orders to taker into consideration any information asymmetry, as documented in the literature. The informed traders' submission rate on the bid and ask side is then regressed on the hour-of-the-day dummy variables.

[9] There is only 20 minutes in the first interval as it takes around 10 minutes for all stocks on the ASX to officially open. The opening prices are obtained at approximately 10:10:00 am.

$$Inf_{i,t} = \alpha_i + \beta_i Time1_{i,t} + \gamma_i Time2_{i,t} + \lambda_i Time3_{i,t} + \phi_i Time5_{i,t} + \theta_i Time6_{i,t} + u_i \quad (1)$$

Where *Time1*, *Time2*, *Time3, time4*, *Time5 and Ttime6* are dummy variables denoting the hour-of-the-day effect on a trading day between 10:10:00 to 16:00:00.[10] For instance, the dummy variable *time1* equals 1 for orders submitted within the first hour of opening on the ASX, 10:10 - 11:00, and 0 otherwise; dummy variable *time2* equals 1 for orders submitted or executed over the second hour of the trading day, 11:00 - 12:00, and 0 otherwise, and so on and so forth for the rest of them.

The results are presented in Table 3. In both the buying and selling order equations the estimated coefficients convey a similar message. Overall, the informed traders' limit order submission rate, as measured by the percentage of limit orders used by informed traders in all orders, is a function of the time-of-the-day effects in more than 40 stocks. A significant negative coefficient for *time5* (13:00 – 14:00) in approximately half of the stocks implies that there are fewer informed traders present over that time period. This is consistent with the 'U' shaped pattern of informed traders observed in Figure 1, where the curve reaches its bottom during the period from 13:00 to 14:00. What draws our most attention is however seeing the largest positive diurnal effect on the informed traders' submission rate from *Time5* and *Time6*, the last two hours before closing, and this is significant in more than 40 stocks. The largest mean values in these two coefficients suggest that informed traders increase their use of limit orders in these two hours more than at any other time through the trading day. The increased limit order submission rate of informed traders provides evidence of them taking a role to provide liquidity and thus they become quasi-market makers as the day progresses. This is

[10] The lunch time hour from 12:00 to 13:00 denoted by *Time4* is included in the intercept to avoid singularity.

consistent with the findings of Bloomfield et al. (2005) in an experimental study that liquidity provision changes through time due to the differing behaviour of informed traders in their placement of limit orders.

However, another important aspect of the evolution of liquidity in the literature, which motivates informed traders to become liquidity providers by using more limit orders towards the end of trading day, is that informed traders are not exposed to the same risk as the other traders because of their information advantage. The current section of the paper attempts to provide empirically evidence in relation to this proposition. Theoretically informed traders do not face uncertainty when they submit limit orders. They are exposed to no risk of adverse selection, and hence can price limit orders more aggressively and be at an inside quote supplying liquidity to the other traders. Therefore, we expect that the limit order submissions of informed traders will lead to a larger impact on the total submitted, and more importantly, the executed volume of limit orders than the limit order submission of the other traders on the market. This is tested in the following two model specifications:

$$\begin{aligned} Sub_{i,t} = {} & a_i^s + b_i^s Sub_{i,t-1} + c_i^s Inf_{i,t} + d_i^s othr_{i,t} + e_i^s Volatility_{i,t} \\ & + f_i^s Avg\_b\_depth_{i,t-1} + g_i^S Avg\_a\_depth_{i,t-1} + u_{i,t}^s; \end{aligned} \tag{2}$$

$$\begin{aligned} Take_{i,t} = {} & a_i^T + b_i^T Take_{i,t-1} + c_i^T Inf_{i,t} + d_i^T othr_{i,t} + e_i^T Volatility_{i,t} \\ & + f_i^T Avg\_b\_depth_{i,t-1} + g_i^T Avg\_a\_depth_{i,t-1} + u_{i,t}^T; \end{aligned} \tag{3}$$

The dependent variables in Equation (2) and (3), $Sub_{i,t}$ and $Take_{i,t}$, represent the diurnally adjusted[11] total number of submitted limit orders and executed limit orders in the form of the natural logarithm at interval t for stock i, respectively. The purpose of the diurnal adjustment is to eliminate the effect of the time-of-the-day on both the dependent and independent variables which can result in biased estimates. The correlation coefficients between the time-of-the-day dummy variables and all variables are presented in Table 4. A significant correlation is evident between the dependent/independent variables and the diurnal dummy variables. *Inf* is defined as above, the limit order submission rate of informed traders, whereas *othr* denotes the limit order submission rate of the other traders, including liquidity traders and the hybrid traders who do not fall into our definition of informed or liquidity traders. There are also three control variables. Volatility is calculated in a way similar to Ahn et al. (2001) from sums of squared returns in each interval, that is, $volatility = \sum_n r_n^2$.

Avg_b_depth and *Avg_a_depth* are the average depth in logarithm (measured in shares) at the best bid and ask price. As the bid and ask orders are estimated separately, we are able to control for the differing effect of bid/ask depth on the submission and execution of limit orders.

The equation (2) is estimated first, where the diurnal adjusted total number of limit orders submitted is regressed on the limit order submission of the informed and the

[11] In the diurnal adjustment estimation each of the two dependent variables is regressed on the time-of-the-day dummy variables, *Time1*, *Time2*, *Time3*, *Time4*, *Time5*, and *Time6*, as defined above, and one lag of itself, then the residual series is used as the dependent variable in Equation (2) and (3). All coefficients are found to be significant. The estimation results are available on request.

other traders, and the control variables, on the bid and ask equations of each stock. A summary of the results is presented in Table 5. Our first impression is that the number of limit orders submitted on both the bid and ask sides is significantly affected by all independent variables: the realized volatility, the limit order submission rates of informed and the other traders, and the bid/ask market depth for majority of the stocks. The significance of volatility in limit order submission has been widely documented in the literature[12].

Some distinctive contrast between the results from the selling order and buying order equations are noted. The market depth on the bid and the ask side has opposing effects on the submission of the buying and selling orders. A thick bid depth observed from the last period tends to attract buying orders in this period as it provides positive information about the stock, whereas stacks of orders placed on the ask side sends out signals to sell the stock. Taking the bid equation as an example, with a positive average mean of 0.33, every 1% increase in the lagged average bid depth increases the total submitted limit orders to purchase a stock by an average of 0.33%, statistically significant in all 50 stocks,

It is not surprising that both *Inf* and *Othr* are markedly significant, as the limit order submission rates of both types of trades are after all a direct factor to the total submitted limit orders on the market. It is however worth noting that the larger magnitude of the coefficient with the higher level of significance in the informed traders' submission rate suggests a bigger role played by informed traders in liquidity provision despite the fact that they only account for 26% (shown in Table 2) of the total volume on the market.

[12] See Bae, Jan and park (2003) and Ahn, Bae and Chan (2001) for reference.

Nevertheless, we know that the total submitted volume is a noisy measure as many limit orders submitted can be subsequently amended, cancelled, or lapsed through time. Another measure that is believed to be better is the total executed volume of limit orders. For example, the relation between the total executed limit orders and certain traders' submission rates is an indication of whether these types of traders are effective in their limit order strategy as it detects to what degree the limit orders submitted are executed. Therefore, in the next stage of analysis we estimate regressions of executed limit orders on the same independent variables, as shown in Equation (3). The results are summarised in Table 6.

Table 6 provides regression results of total executed limit orders on the submission rates of informed and the other traders, and the control variables. All variables remain statistically significant in most stocks. As far as the lagged average depths are concerned, it is interesting to see this time it is the depth on the other side (say, the ask side) that exerts a slightly larger effect on the executions of buying orders, and vice versa for selling orders. The explanation is intuitive as a successful execution involves orders from both sides. For example, the execution of a limit order on the bid side depends on a market order submitted on the ask side (to sell a stock), but an investor would usually look at the depth on the same side (ask side) to decide whether he should sell this stock using a market or limit order.

When the mean coefficients of the limit order submission rates of the informed and the other traders are compared, all positive and significant for more than 40 stocks, the larger value in the informed submission rate indicates that informed traders are more

strategic in their order placing strategy as their limit orders lead to more executions than those of the other traders, and this is true for orders both submitted to purchase or sell. To give an example, in the ask equation, a 1% increase in the submission rate of informed traders' limit orders will increase the total executed volume of limit orders by 1.59%, and a 1% increase in the submission rate of the other traders' limit orders will only increase the total executed volume of limit orders by 0.52%. The impact of informed traders' limit order submission on the total executed volume is considered even more substantial when it is considered that on the market the limit orders of informed traders only account for 26% of the total volume of limit orders (Table 2).

Our analysis provides empirical evidence to support Bloom et al's (2005) proposition about the information value possessed by informed traders and how they can make use of it. With private information about the true value of the stock, the informed traders are exposed to a lower degree of both un-execution risk and risk of adverse selection, and are therefore more successful in their use of limit orders.

4.3 Robustness tests

To examine the consistence of our coefficients some robustness tests are performed. First, we use data aggregated at different time intervals, such as 10 minutes, 30 minutes and 1 hour. The degree of significance in coefficients is found to be similar. Secondly, the regressions are also estimated with all orders regardless of whether they are bid or ask orders. While other variables remain significant, the signs of the bid/ask depth are mixed and the econometric efficiency of the model is jeopardised.

5. Conclusion

This paper investigates the order behaviour of different types of traders on the ASX, a typical order driven trading system, using the limit order book data from SIRCA. Contrary to early theoretical predictions that informed traders prefer market orders, we find strong evidence of informed traders' use of limit orders, as well as the evolution of liquidity over time during a trading day. The greatest increase of informed traders' use of limit orders is during the last two hours before closing. This provides empirical evidence that they take on a role as quasi market makers by providing liquidity as the end of trading approaches as proposed in the experimental framework. We also find evidence that the information value processed by informed traders makes them more successful in their limit order strategy as they are not exposed to non-execution risk and adverse selection risk to the same degree as the other traders. This impact is considered very substantial as in our sample the volume of limit orders from informed traders under-weighs that of the other traders by a large amount.

The order strategy of liquidity traders displays a relatively flat "U" shaped pattern with more limit orders being used at the opening. This is consistent with the theory and findings on other markets that they try to protect themselves from trading with informed traders who are taking advantage of the over night arrival of information through trading aggressively at opening.

Lastly, the pattern of the informed traders' order placement shows an increase in the use of market orders. This is a direct result from the unique trading mechanism which entails the presence of a closing call auction as applied on the ASX. Traders that have

information about the true value of stocks would like to act on it quickly through the use of market orders before the continuous trading platform closes at 16:00:00. If the close price obtained from the closing call auction at 16:15:00 is assumed to reflect all information on the market, then our finding may be an indication that the surge in the use of market orders is a manifestation of (informed) traders' proactive exploitation of their informational advantage before prices adjust.

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Table 1. Distribution of cumulative price change, volume and number of transactions

Size group		*% cumulative price change*	*% volume*	*% no. trades*
A. The whole sample period.				
Small	(0 - 1,999 shares)	-126.88	5.53	48.82
Medium	(2,000-49,999 shares)	183.89	59.67	49.24
Large	(50,000 + shares)	43.00	34.80	1.94
B. The second half of the sample period where the market experienced a 5% increase.				
Small	(0 - 1,999 shares)	1.09	6.67	52.72
Medium	(2,000-49,999 shares)	90.46	59.17	45.97
Large	(50,000 + shares)	8.45	34.16	1.31

Note: this table provides a distribution of percentage of price change, volume and number of transactions according to order sizes for S&P50 on the ASX. Panel A includes all stocks for the whole sample period. Panel B includes all stocks from the second half of the sample, from 13 Mar – 30 June 2003, where the market had increased by around 5%. The classification of order sizes takes into account the scale of the Australian Stock Exchange relative to that of the NYSE. Our classification is consistent with Barclay and Warner (1993) in that the small size group accounts for around 50% of all orders in the sample. The percentage of the cumulative price change for a given stock is obtained by dividing the cumulative return of the stock for the order size by the total cumulative stock return over the sample period. The percentage of the volume is calculated as the total volume of a order size as a percentage of the total trading volume. The percentage of the number of orders is computed as the number of transactions of a order size divided by the total number of transactions of all order size groups.

Table 2 Descriptive statistics

	No. of Orders		Volume	
	Market Orders	Limit Orders	Market Orders	Limit Orders
Total	2,404,991	3,844,837	21,122,897,687	49,790,091,254
Informed traders (%)	30.67	35.32	34.42	25.72
The other traders (%)	69.34	64.68	65.57	74.29
Liquidity traders	35.79	31.96	18.39	16.44
Hybrid traders	33.55	32.72	47.18	57.85

Note: this table provides descriptive statistics to the three groups of traders, the informed traders, the liquidity traders, and the hybrid traders who do not fall into our definition of informed or liquidity traders. It shows the total market and limit orders submitted over the sample period measured in the number of orders and number of shares, respectively, and the proportion used by each type of traders. The informed traders are defined as those who are 'institutional', and submit orders in medium sizes (2,000-49,999 shares). The liquidity traders are those classified as 'retail' by the ASX. The 'other' traders are those classified as 'other' by the ASX, plus those institutional traders who submit small or large orders.

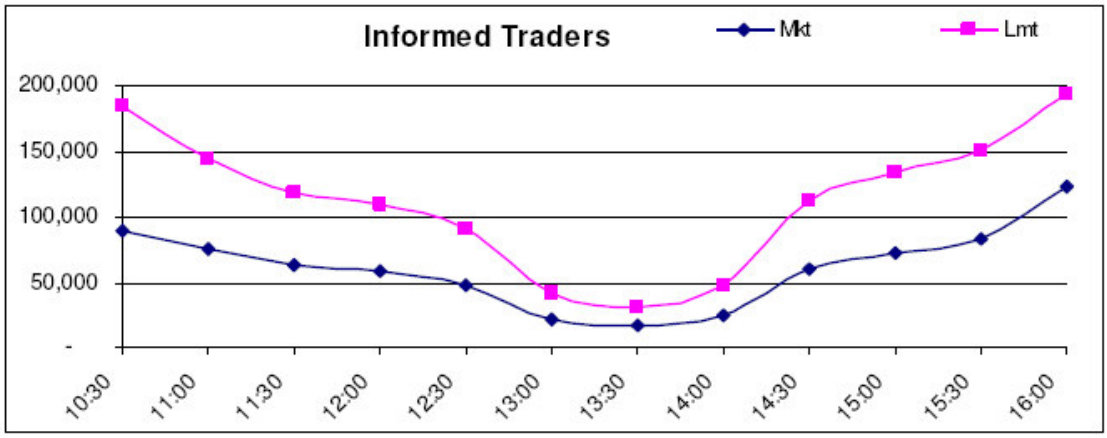

Figure 1. The number of market and limit orders submitted by informed traders

Note: this diagram depicts the number of market and limit orders submitted by informed traders over the trading hours on the ASX for all sample stocks. The continuous trading phase on the ASX is from 10:10:00 to 16:00:00. The opening prices are calculated between 10:00:00 and 10:10:00 from an open call auction, and the closing prices are obtained at around 16:10:00 in a Closing Single Price Auction process. During the Pre Closing Single Price Auction (CSPA) stage between 16:00 and 16:10, only limit orders are allowed as there is no execution of orders. The informed traders are defined as those who are 'institutional', and submit orders in medium sizes (2,000-49,999 shares).

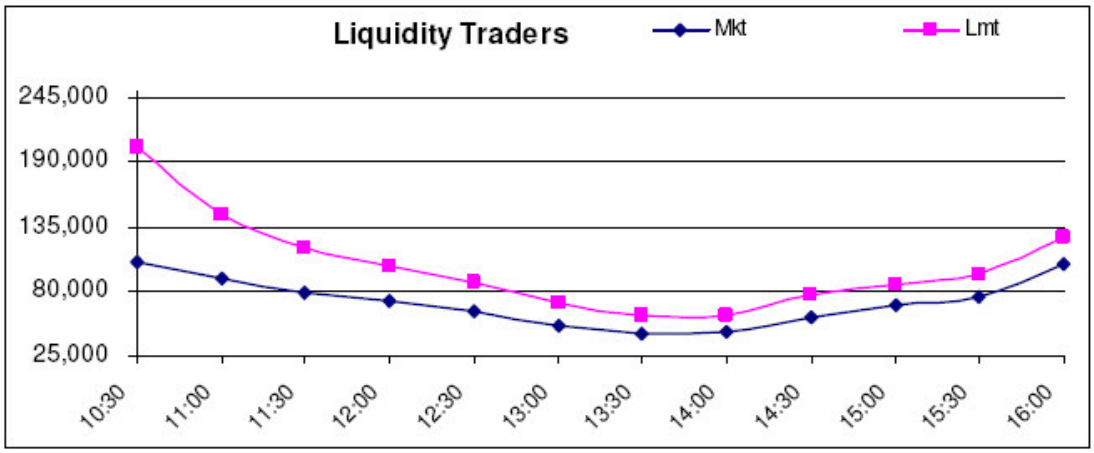

Figure 2. The number of market and limit orders submitted by liquidity traders

Note: this diagram depicts the number of market and limit orders submitted by informed traders over the trading hours on the ASX for all sample stocks. The continuous trading phase on the ASX is from 10:10:00 to 16:00:00. The opening prices are calculated between 10:00:00 and 10:10:00 from an open call auction, and the closing prices are obtained at around 16:10:00 in a Closing Single Price Auction process. During the Pre Closing Single Price Auction (CSPA) stage between 16:00 and 16:10, only limit orders are allowed as there is no execution of orders. The liquidity traders are those classified as 'retail' by the ASX.

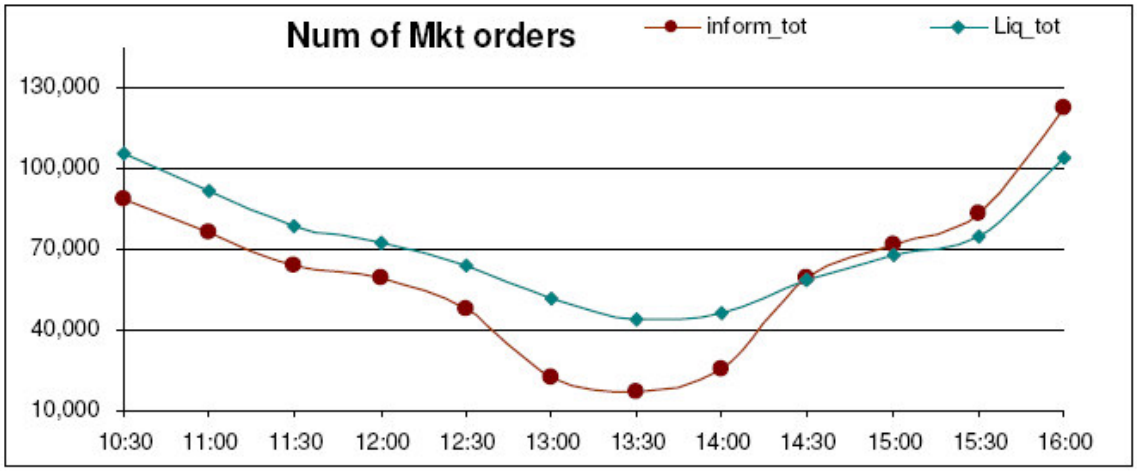

Figure 3. The number of market submitted by the informed and the liquidity traders

Note: this diagram compare the number of market orders submitted by informed and liquidity traders over the trading hours on the ASX for all sample stocks. The continuous trading phase on the ASX is from 10:10:00 to 16:00:00. The opening prices are calculated between 10:00:00 and 10:10:00 from an open call auction, and the closing prices are obtained at around 16:10:00 in a Closing Single Price Auction process. During the Pre Closing Single Price Auction (CSPA) stage between 16:00 and 16:10, only limit orders are allowed as there is no execution of orders. . The informed traders are defined as those who are 'institutional', and submit orders in medium sizes (2,000-49,999 shares). The liquidity traders are those classified as 'retail' by the ASX.

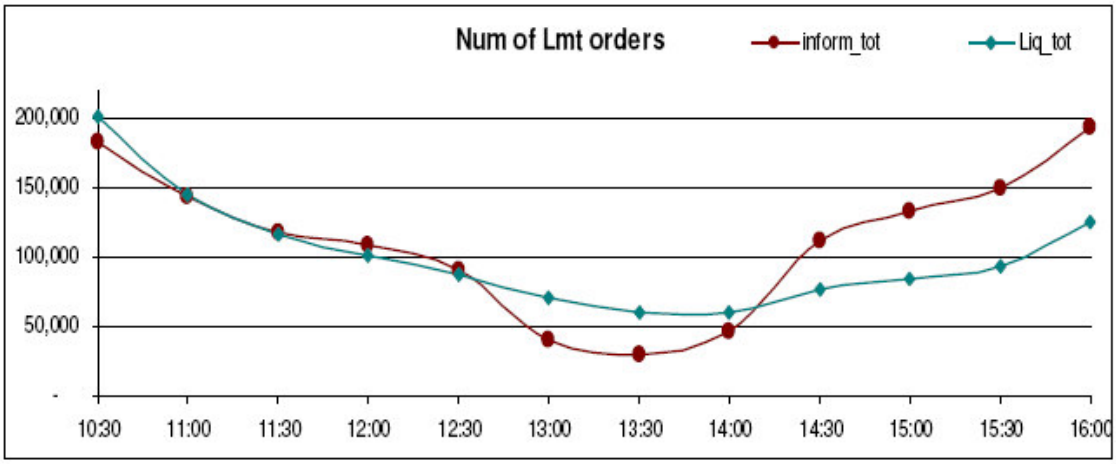

Figure 4. The number of limit orders submitted by informed and liquidity traders

Note: this diagram depicts the number of limit orders submitted by informed and liquidity traders over the trading hours on the ASX for all sample stocks. The continuous trading phase on the ASX is from 10:10:00 to 16:00:00. The opening prices are calculated between 10:00:00 and 10:10:00 from an open call auction, and the closing prices are obtained at around 16:10:00 in a Closing Single Price Auction process. During the Pre Closing Single Price Auction (CSPA) stage between 16:00 and 16:10, only limit orders are allowed as there is no execution of orders. The liquidity traders are those classified as 'retail' by the ASX.

Table 3 Informed traders' limit order submission rate on the time-of-the-day effect

	Intercept	*time1*	*time2*	*time3*	*time5*	*time6*	*Avg_r²*
Ask Equation							
Coeff.	0.18	0.03	0.02	-0.01	0.04	0.05	0.05
Std error	0.00	0.11	0.19	0.23	0.05	0.06	
t-stats	21.44	2.89	2.15	-1.20	4.29	4.57	
No. of significance		**37**	**32**	**24**	**43**	**42**	
Bid Equation							
Coeff.	0.19	0.02	0.03	-0.01	0.04	0.04	0.05
Std error	0.00	0.21	0.11	0.26	0.06	0.08	
t-stats	21.89	2.21	2.50	-1.38	4.20	4.25	
No. of significance		**31**	**34**	**25**	**43**	**40**	

Note: this table reports OLS results of the informed traders' limit order placement rate the time-of-the-day dummies in Equation (1). The dependent variable, the submission rate of informed traders, is computed as the number of limit orders submitted by informed traders on the sum of their limit plus market orders in each interval of 30 minutes. The estimation is performed separately for selling and buying orders and presented in two separate panels. Independent variables *Time1*, *Time2*, *Time3, time4*, *Time5 and Ttime6* are dummy variables denoting the hour-of-the-day effect on a trading day between 10:10:00 to 16:00:00. For instance, the dummy variable *time1* equals 1 for orders submitted within the first hour of opening on the ASX, 10:10 - 11:00, and 0 otherwise; dummy variable *time2* equals 1 for orders submitted or executed over the second hour of the trading day, 11:00 - 12:00, and 0 otherwise, and so on and so forth for the rest of them.

Table 4 Pearson Correlation Coefficients

	Submissions	*Executions*	*Volatility*	*Inf_p*	*othr_p*
Bid Equation					
time1	0.16*	0.11*	0.01*	0.03*	0.09*
time2	0.20*	0.19*	0.00	0.07*	-0.12*
time3	0.06*	0.04*	0.00	0.00	0.01*
time4	-0.14*	-0.13*	0.00	-0.07*	0.04*
time5	-0.35*	-0.27*	0.00	-0.10*	0.05*
time6	0.06*	0.04*	0.00	0.06*	-0.06*
Ask Equation					
time1	0.16*	0.10*	0.02*	0.01*	0.07*
time2	0.20*	0.19*	0.00	0.07*	-0.14*
time3	0.068	0.05*	0.00	0.02*	0.00
time4	-0.15*	-0.12*	-0.01	-0.06*	0.05*
time5	-0.35*	-0.27*	-0.01	-0.10*	0.09*
time6	0.06*	0.05*	0.00	0.07*	-0.06*

This table presents Pearson Correlation Coefficients of the hour-of-the-day dummy variables and a number of variables under H0: Rho=0. * indicates coefficients at 5% significance level. *Submissions* and *Executions* represent the natural logarithm of the total submitted and executed limit orders in a given interval. Volatility is the realized volatility calculated in a way similar to Ahn et al. (2001) from sums of squared returns. *Inf* is the limit order submission rate of informed traders, whereas *othr* denotes the limit order submission rate of the other traders, including liquidity traders and the who do not fall into our definition of informed or liquidity traders. *Time1*, *Time2*, *Time3, time4*, *Time5 and Ttime6* are dummy variables denoting the hour-of-the-day effect on a trading day between 10:10:00 to 16:00:00. For instance, the dummy variable *time1* equals 1 for orders submitted within the first hour of opening on the ASX, 10:10 - 11:00, and 0 otherwise; dummy variable *time2* equals 1 for orders submitted or executed over the second hour of the trading day, 11:00 - 12:00, and 0 otherwise, and so on and so forth for the rest of them.

Table 5 The effect of submitted limit orders on trader identity

	Intercept	Sub_{t-1}	*Volatility*	*Inf*	*Othr*	*Ask_depth*	*Bid_depth*	Avg_r^2
Submitted buying limit orders								
Coeff.	-5.13	0.12	0.04	2.46	1.77	0.07	0.33	0.26
Std error	0.00	0.09	0.00	0.01	0.01	0.23	0.00	
t-stats	-13.41	5.40	6.73	12.15	10.22	2.04	9.25	
Number of significance		42	50	49	49	27	50	
Submitted selling limit orders								
Coeff.	-4.56	0.11	0.04	2.84	1.85	0.22	0.12	0.26
Std error	0.00	0.09	0.00	0.00	0.00	0.01	0.08	
t-stats	-11.90	5.14	5.87	13.60	10.46	5.99	3.37	
Number of significance		41	50	50	50	48	40	

Note: this table reports regression results of the submitted buying and selling limit orders on a number of independent variables. The dependent variables, the natural logarithm of the submitted buying and selling limit orders, are diurnal adjusted first, where each of the two variables is regressed on the time-of-the-day dummy variables, *Time1, Time2, Time3, Time4, Time5* and *Time6*, and one lag of itself. The purpose of the diurnal adjustment is to eliminate effect of the time-of-the-day on both the dependent and independent variables which can result in biased estimates. *Inf* is the limit order submission rate of informed traders, and *othr* denotes the limit order submission rate of the other traders, including liquidity traders and the hybrid traders who do not fall into our definition of informed or liquidity traders. There are also three control variables: Volatility, calculated in a way similar to Ahn et al. (2001) from sums of squared returns in each interval; *Avg_b_depth* and *Avg_a_depth*, the average depth in logarithm (measured in shares) at the best bid and ask price.

Table 6 The effect of executed limit orders on trader identity

	Intercept	$Take_{t-1}$	*Volatility*	*Inf*	*Othr*	*Ask_depth*	*Bid_depth*	Avg_r^2
Executed buying orders								
Coeff.	-3.57	0.10	0.05	0.89	0.11	0.19	0.14	0.09
Std error	0.02	0.15	0.03	0.09	0.20	0.12	0.12	
t-stats	-5.29	3.76	4.88	2.68	0.21	3.09	2.31	
Number of significance		35	48	41	34	36	32	
Executed selling orders								
Coeff.	-3.44	0.10	0.05	1.59	0.52	0.12	0.18	0.09
Std error	0.01	0.13	0.03	0.04	0.16	0.22	0.14	
t-stats	-5.23	3.73	4.45	3.93	1.17	2.07	3.01	
Number of significance		38	46	44	33	30	39	

Note: this table reports regression results of the executed buying and selling limit orders on a number of independent variables. The dependent variables, the natural logarithm of the executed buying and selling limit orders, are diurnal adjusted first, where each of the two variables is regressed on the time-of-the-day dummy variables, *Time1, Time2, Time3, Time4, Time5* and *Time6*, and one lag of itself. The purpose of the diurnal adjustment is to eliminate effect of the time-of-the-day on both the dependent and independent variables which can result in biased estimates. *Inf* is the limit order submission rate of informed traders, and *othr* denotes the limit order submission rate of the other traders, including liquidity traders and the hybrid traders who do not fall into our definition of informed or liquidity traders. There are also three control variables: realized volatility, calculated in a way similar to Ahn et al. (2001) from sums of squared returns in each interval; *Avg_b_depth* and *Avg_a_depth*, the average depth in logarithm (measured in shares) at the best bid and ask price.