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Some evidence on the information content of undisclosed limit orders on the ASX

M. Aitken
David E. Allen
Wenling J. Yang
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By

M. Aitken
SIRCA, University of New South Wales, and CMCRC

D. E. Allen*
Edith Cowan University

And

W.J. Yang
Edith Cowan University, SICRA, and CMCRC

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*Correspondence author and address:

Professor David E. Allen
School of Accounting, Finance and Economics
Edith Cowan University
100 Joondalup Drive
Joondalup WA 6027
Australia
Phone: 61+ 8 6304 5471
Fax: 61+ 8 6304 5271
Email: d.allen@ecu.edu.au
Abstract

This paper is concerned with investigating the information content of undisclosed limit orders, and identifying factors that affect their size, plus the examination of the brokers’ behaviour in using undisclosed orders. We adopt a sample of liquid stocks listed on the ASX, and our estimation results indicate that the size of undisclosed orders are affected by a number of factors. Given the ‘stealth trading’ pattern of behaviour observed in large disclosed orders, this paper provides evidence to support a similar pattern of behaviour in the case of undisclosed orders. Our model also provides an appropriate measure for estimating the size of undisclosed orders.

Keywords: Undisclosed limit orders; ARMA model; liquidity; volatility

JEL Classification: C2; G12

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1. **Introduction**

Given the increasing use of automated trading systems by stock exchanges, liquidity and transparency have nowadays become two essential qualities for operators of financial markets to consider. From the markets’ point of view, liquidity means the ability for a trader to buy or sell any amount of stocks immediately and at a price not far away from the current market price (Black (1971)). It is the element in market microstructure that has received much attention and research on it has made remarkable advances at both the theory level (see Kyle (1985), Easley, Kiefer, O’Hara and Papermen (1996)) and empirical level (O’Hara (1995), Engle and Defour (1998), etc.). The other important feature of a trading system is market transparency\(^1\), defined by O’Hara (1995) as the ability of market traders to observe trading information during the trading process, where information can refer to knowledge about current or past prices, quotes, volume, the source of order flow, the identities and motivations of market participants (Madhavan (1996)). Of all these dimensions of transparency, the issue concerning the disclosure of information on quotes and transactions have been central to regulation debates. Biais (1993) argues that quotation transparency will increase market efficiency and increase liquidity. Lyons (1994) states that the lack of trade disclosure causes excess volatility in the foreign exchange market. According to the microstructure theory, the greater the chance of trading with an informed trader, the higher the market maker sets his next bid and ask spread. Therefore, if a lower bid and ask spread is observed in the market, it means that the informed traders are hiding themselves well amongst liquidity traders, exploiting the potential benefit from the superior information they possess. Madhavan (1995) argues that block trade brokers and institutional investors who are generally more informed than the other market traders prefer trading in lower transparency markets in order to conceal their information advantage and also to protect themselves from the large price impact cost that is partially caused from the high bid and ask spread.

In order-driven markets that electronic order book systems prevail, and traders are requested to offer liquidity to the system by submitting limit orders as an indication that they are willing to trade. These traders are called liquidity suppliers. Then the liquidity demanders, the counterparty of liquidity suppliers, submit market orders for immediate execution in response to trading opportunities liquidity suppliers give them. To be successful, stock exchanges must encourage liquidity suppliers to publicly display their limit orders so that liquidity demanders can be attracted. The profit that comes from the premium between the market price and limit price liquidity suppliers specify is paid by liquidity demanders for an
immediate execution. In the meantime, however, liquidity suppliers expose themselves to the risk of trading with better informed traders and parasitic traders such as front runners, squeezers, quote matchers and so on, see Harris (1997) for details. Therefore, while enhancing their market transparency of limit orders for liquidity offer, order-driven system exchanges as the Australian Stock Exchange (ASX), the Paris Bourse and the Toronto Stock Exchange have compiled rules to protect traders from unnecessary order exposure. That traders are allowed to submit undisclosed orders is one of these rules. In other words, brokers are allowed to enter limit orders to the trading system with part or total quantity of this order not revealed to the market participants. Nevertheless, most stock exchanges require a minimum value for submitting an undisclosed order, for instance, for stocks listed on the ASX the total value of an order has to be no less than AUD$200,000 to be entered as an undisclosed order.

Undisclosed orders that allow traders to show other market participants only a part of the total quantity they wish to trade are becoming a frequently used means by stock brokers and institutional traders to avoid substantial exposure of their trading intentions. Previously several studies have considered the use of undisclosed orders with respect to order exposure (Harris, 1996, 1997) and the response of market movements after undisclosed orders submission (Aitken, Berkman and Mak (2001)). However, when it comes to more specific questions of what determines the size of an undisclosed order and what process brokers take to submit the undisclosed limit orders, we need a further investigation into the variables that are related to undisclosed orders. This paper provides explanations to some of these issues in the analysis of market factors that affect the use and the size of the undisclosed orders in an Autoregressive Moving Average framework, as applied to ASX data.

Many previous studies have found a positive relationship between the absolute value of price changes and trading volume, so in this ARMA model, the absolute price change from the last close price and the last five minutes are incorporated to measure the long-term and short-term volatility of price movements prior to the submission of an undisclosed order. In the meantime, an appropriately specified model should also capture the change in liquidity that has an impact on the size of undisclosed orders, the time of the day effect, the degree of information existing, and the trading pattern of the individual broker. A detailed description of each variable used to capture these factors is provided in the next section.

Through the analysis of undisclosed orders in this paper, we have also analysed the patterns that are followed by brokers in their submission of undisclosed orders on stock markets. As there is a minimum value requirement for the submission of undisclosed orders, the undisclosed orders are most often used by block traders and institutional investors who
trade stocks in large quantities. The behaviour of block traders and institutional investors has been the focus of Chan and Lakonishok (1993, 1995) and Keim and Madhavan (1995, 1996). Recent studies by Chan and Lakonishok (1995) on block trades have found evidence that block traders and institutional investors prefer to break up a large orders into smaller sized orders before entering the market. This is explained as a strategy used by block traders to protect them from the various risks of trading with parasitic traders, see Harris (1997). Barclay and Warner (1993) have found evidence on the US stock market that medium size trades mostly drive price movements. The examination of how and under what conditions block traders use undisclosed orders to hide their large positions as an alternative strategy in the market gives a better understanding of institutional traders’ behaviour from a different angle that has not been explored before. Moreover, as we focus on examining the patterns revealed in entering and dealing with undisclosed orders from an individual stockbroker’s point of view, the explicit estimation of current undisclosed order size associated with previous undisclosed orders entered by the same broker provides important implications for predicting the size of the undisclosed orders.

The remainder of this paper is organised as follows. Section two outlines the institutional framework of the ASX and the data set we are using in the model. Section three illustrates our modelling methodology and implements the model specified and the variables. Section four presents the results we obtain, giving explanations and implications and section five concludes the paper.

2. Market Description and the Data

The automatic order driven markets have their own electronic screen-trading system, for instance, the Australian Stock Exchange uses the Stock Exchange Automated Trading System (SEATS) for stock trading. The SEATS provides an order-driven market where matched bids and asks entered based on price time priority can be automatically executed. SEATS screen places unexecuted limited orders in a queue in sequence of price and time with quote details displayed publicly: trade type (bid/ask), price, broker number and quantity. Brokers have the option to hide their quantity if the total value of the order is above a level of the undisclosed order threshold. The quantity of an undisclosed order may also be partially disclosed and partially undisclosed, provided the undisclosed portion is at least the size of the undisclosed order threshold. On the ASX the undisclosed order has precedence over disclosed order given
the same price, and as soon as the undisclosed quantity falls below the threshold during the course of trades, the full order quantity becomes disclosed.

Using Australian intra-day data, Aitken, Brown and Walter (1996) show that in 1993 about 6% of orders on the ASX are undisclosed accounting for approximately 28% of the volume. On the French market D’Hondt, Winne and Francois-Heude (2001) find that 14% of limit orders are not totally disclosed, which account for 45% of the proposed volume. Moreover, for those partially disclosed orders, the undisclosed portion is increasing with the total order size, with roughly more than 70% of orders hiding more than 70% of the total number of shares. In a cross-sectional framework, Berkman, Aitken and Mak (2001) find that the use of undisclosed orders of a stock increases with the volatility that is measured by the average daily high-low spread as a fraction of the price. In this paper we undertake a time-series study for ASX stocks to explicitly examine the impact of market volatility and excessive trading volume on the size of undisclosed orders.

The data is provided by the Security Industry Research Centre of Asia-Pacific (SIRCA). It includes detailed order submission information as the order initiator, the price, the disclosed and undisclosed quantity, the entry time, and the broker ID of the broking house who enters the order for a period of three months from December 4th 2000 to February 26th 2001. Then those orders in our sample having undisclosed quantities are pulled out to form a new sample of undisclosed orders for further investigation. After this filtering approximately 2500 observations are included in the sample, with 57.3% bids and 43.7% asks. In order to eliminate the influence of abnormal trading activity during the opening and closing of the market (Engle and Russell (1998)), this study only examines orders submitted between 10:30 am and 3:30 pm when market is considered at its normal continuous trading stage. Moreover, an undisclosed order is counted only at the time when it is entered, so any amendment, expiration and deletion of this order is not considered nor included. This is to avoid repeated computation of orders and excessively unnecessary autocorrelation in the data sets.

For further investigation and model estimation, we have chosen three stocks listed on the ASX that have the greatest number of undisclosed orders entered and do not go ex-dividend during the sample period. These three stocks are BHP, NAB and TLS from resource, banking and telecommunications sector, respectively. The order details of these stocks are presented in Table 1 below.
### Table 1: Descriptive Statistics of Undisclosed Volume and Price

<table>
<thead>
<tr>
<th></th>
<th>BHP</th>
<th>NAB</th>
<th>TLS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buying Side:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discl. Size</td>
<td>52,790</td>
<td>23,967</td>
<td>229,074</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>1.20%</td>
<td>0.85%</td>
<td>1.29%</td>
</tr>
<tr>
<td>Min.</td>
<td>5,830</td>
<td>3,500</td>
<td>14,300</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>0.13%</td>
<td>0.12%</td>
<td>0.08%</td>
</tr>
<tr>
<td>Max.</td>
<td>499,999</td>
<td>200,000</td>
<td>1,100,000</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>11.34%</td>
<td>7.12%</td>
<td>6.20%</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>73,156.3</td>
<td>34,642.4</td>
<td>216,879.1</td>
</tr>
<tr>
<td><strong>Selling Side:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discl. Size</td>
<td>63,036</td>
<td>53,847</td>
<td>154,096</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>1.43%</td>
<td>1.92%</td>
<td>0.87%</td>
</tr>
<tr>
<td>Min.</td>
<td>5,000</td>
<td>3,500</td>
<td>14,435</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>0.11%</td>
<td>0.12%</td>
<td>0.08%</td>
</tr>
<tr>
<td>Max.</td>
<td>500,000</td>
<td>500,000</td>
<td>3,000,000</td>
</tr>
<tr>
<td>As % of Daily Vol.</td>
<td>11.34%</td>
<td>17.81%</td>
<td>16.91%</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>106,365.4</td>
<td>97,231.4</td>
<td>253,720.8</td>
</tr>
</tbody>
</table>

| Daily Trading Vol:   | 4,409,763  | 2,807,871  | 17,737,877 |

Notes: The Undis. Vol. represents the size of the undisclosed order for each stock. The Daily Vol. is calculated as the average daily trading volume for each of the three stocks in the three months of our sample period.

On the buying side as shown in the first panel of Table 1, TLS has the largest average undisclosed order size of approximately 230,000 shares during the sample period, accounting for 1.3% of its average daily trading volume. NAB has the largest price movements as reflected in the standard deviation of the price, while the mean size of the undisclosed order in NAB only accounts for 0.85% of its average daily trading volume. This is however not the case on the selling side. With the greatest price deviation of the three, though NAB has the smallest mean size of 53,847 shares, it accounts for 1.92% of its average daily trading volume, highest of the three. This suggests that the undisclosed order size is more significant on the selling side. With the greatest price deviation of the three, though NAB has the smallest mean size of 53,847 shares, it accounts for 1.92% of its average daily trading volume, highest of the three. This suggests that the undisclosed order size is more significant on the selling side.
53,847 shares, it accounts for 1.92% of its average daily trading volume, highest of the three. This suggests that the undisclosed orders are used more on the selling of NAB then the purchasing of it. On the contrary, the opposite is true for TLS, for the mean size of the undisclosed order only accounts for 0.87% of its average trading volume, as opposed to 1.3% on the purchasing side.

3. The Model for Undisclosed Orders

To examine the factors that determine the size of undisclosed orders, we consider the following two aspects. First, several studies have tested the interaction between trading volume and price volatility at constant data frequency interval\(^4\). For intra-day data at order level, the trading volume of a trade is actually the order size. To capture the potential impact of volatility on the size of undisclosed orders, the model incorporates in the short-term and long-term price volatility variables that are measured as the absolute price change from the last five minutes before the order submission, and from the close-price on the previous day, respectively. This can be expressed in the following equations as:

\[
\Delta p_{5\text{min}} = \ln \left( \frac{P_m}{P_{5\text{min}}} \right) \quad (1)
\]

\[
\text{ABS} \left( \Delta p_{5\text{min}} \right) = | \Delta p_{5\text{min}} | \quad (2)
\]

\[
\Delta p_{\text{close}} = \ln \left( \frac{P_m}{P_{\text{close}}} \right) \quad (3)
\]

\[
\text{ABS} \left( \Delta p_{\text{close}} \right) = | \Delta p_{\text{close}} | \quad (4)
\]

Secondly, many authors have addressed the issue of the information content of liquidity. Essentially, liquidity is associated with frequent trading at low costs. Previous studies have used the bid/ask spread and the difference between daily high and low to proxy for it. In this context, liquidity is associated with the number of orders that are executed within a certain period of time\(^5\) with no significant price changes in the stock. The total trading volume from the start of the trading day to the time spot when an undisclosed order is submitted for the stock is thus calculated to compare with the average level of this measure across the previous 30 trading days. The change of liquidity on the day of submission from its average level is an indicator of whether there is new information existing on the market before an undisclosed order is submitted. This is an important factor which may affect the brokers’ use of undisclosed orders. In formulation, the change of liquidity is measured as the ratio of liquidity
at time before the submission of the undisclosed order to the average value of liquidity from opening to the same time across last 30 days. For example, if the ratio for this undisclosed order entered at 11:00 am in stock \( k \) is 1.5, it means that there is 50% more volume traded today by 11:00 am than normal days, indicating the possibility of new information on the market. This ratio of change in liquidity is expressed in equation (5) as:

\[
\Delta L = \frac{\text{Trading Volume up at } t \text{ of the day}}{\text{Average Trading Volume at } t \text{ over 30 days}} = \frac{V_t}{\bar{V}}
\]  

(5)

As a supplement, the total volume of undisclosed orders entered in the last 5 trading days before the submission of current undisclosed order on bid and ask side \( (UZ_{t}^{bid} \text{ and } UZ_{t}^{ask}) \), respectively, are also included to test the existence of market information in the longer term. Easley and O’Hara (1987) argue that the informed traders always tend to trade in large volume. So if the total volume of the undisclosed orders submitted to either buy or sell a stock during the past five trading days are large, it appears that there has been new public information or informed trading in this stock. In order to conform with other variables in the model, these two variables are then normalised by the stock’s average daily volume calculated over the past 30 trading days,

\[
TV_{t}^{bid} = \ln\left(\frac{\sum UZ_{t}^{bid}}{V_{\text{daily}}}\right)
\]

(6)

\[
TV_{t}^{ask} = \ln\left(\frac{\sum Vol_{t}^{ask}}{V_{\text{daily}}}\right)
\]

(7)

As we use intra-day data sets at order level, the price and volume measures suggest certain patterns during different time of the day. For example, Wood, Mclinsh and Ord (1985) have found an asymmetric \( U \)-shaped pattern in price series across the trading day on the NYSE. Chan Christie and Schultz (1995) observe a similar pattern in trading volume, with larger trading volume at the opening and closing of the trading day. To eliminate this diurnal effect, the time-of-the-day dummies are calculated based on the number of shares submitted in undisclosed orders as a percentage of the average daily trading volume of the stock. First, in our sample that only includes undisclosed orders and variables associated with those undisclosed orders, at order \( i \) we calculate the ratio of As we use intra-day data sets at order level, the price and volume measures suggest certain patterns during different time of the day.
For example, Wood, McInish and Ord (1985) have found an asymmetric U-shaped pattern in price series across the trading day on the NYSE. Chan Christie and Schultz (1995) observe a similar pattern in trading volume, with larger trading volume at the opening and closing of the trading day. To eliminate this diurnal effect, the time-of-the-day dummies are calculated based on the number of shares submitted in undisclosed orders as a percentage of the average daily trading volume of the stock. First, in our sample that only includes undisclosed orders and variables associated with those undisclosed orders, at order \( i \) we calculate the ratio of the total number of shares entered from order one to order \( i \) to the stock’s average daily trading volume. As the order number goes from one to \( i, i+1, \ldots, n \) from the start of the day, this ratio increases upwards across the trading day. Then four dummy variables are identified that differentiate the time when the total number of the undisclosed orders account for respectively 30\%, 40\%, 50\% and 60\% of the stock’s daily volume. For example, if it is the case by 10:37:04 am that the total number of undisclosed orders account for 30\% of the stock’s daily volume, so all undisclosed orders submitted from the start of the trading day to that time have the first dummy variable equal to one, whilst the value of the other three dummy variables are zero for this stock. The other three dummy variables are identified in the similar manner, say, if it is at 03:12:17 pm that the total number of undisclosed orders submitted account for 60\% of the stock’s daily volume, then all undisclosed orders submitted after that time have values of all four dummy variables equal to zero.

It is natural to see that the institutional investors and major brokers who often deal with block trades have been the frequent users of undisclosed orders. A great deal of research has examined the price behaviour associated with the disclosed limit orders in large size orders (block trades) submitted by these traders. It is commonly found that, in order to either avoid high market impact cost, or hide the information advantage they may possess, brokers often break up a large order into a series of moderate size orders. Barclay and Warner (1993) have undertaken research in this regard and propose the “stealth trading” hypothesis that medium size trades drive price movements the most. However, there are brokers and institutional investors’ whose behaviour associated with undisclosed orders has not been investigated. It is suspected that they might also break up a large undisclosed order into a series of moderate size undisclosed orders. If they use the same strategy when submitting their undisclosed orders, then the undisclosed orders submitted consecutively during the course of trading should be somehow correlated. Therefore, an autoregressive moving average (ARMA) framework is applicable in this case to determine the size of the undisclosed order based on its
lags. The significance level of the estimated coefficients will also tell whether brokers use the same ‘breaking-up’ strategy in undisclosed orders as in disclosed limit orders.

The ARMA model employed here is slightly different in its autoregressive (AR) term, the lagged size of the undisclosed orders. Due to the fact that one large undisclosed order is broken up by the same broker and the broken-up orders are therefore more likely to be correlated if they are submitted by the same broker, the AR terms in the model, or the lags of the size of undisclosed orders, are those lags of undisclosed orders submitted by the same broker who enters the current undisclosed order. As each broker has a broker I.D. attached to the order he/she submits in our sample data, it is possible to identify the orders that are submitted by the same broker. For each observation in the dependent variable series, we track 10 trading days back from the current order to find the last undisclosed order submitted by this broker in the same stock, and another 20 trading days to find our second ‘lag’ in the same way. The intuition behind this is that if the broker breaks up a large undisclosed order into a series of smaller undisclosed orders and submits them in sequence \( t_1, t_2, \ldots, t_n \), then orders submitted at \( t_{n+i} \) \( (i = 1, 2, \ldots, n-1) \) should be related to the order submitted at \( t_n \). Only the latest two lags are included in the model as the \( t \)-statistic for longer lags is not statistically significant.

An ARMA model which has incorporated the above-described factors is presented in Equation 6. These factors include price volatility, liquidity, new information, the time of the day and the stockbrokers’ behaviour:

\[
UV_t = c + \alpha_1 UV'_{t-1} + \alpha_2 UV'_{t-2} + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \gamma \Delta L + \varphi \mid \Delta p_{5 \text{min}} \mid + \theta \mid \Delta p_{\text{close}} \mid \\
+ \delta \text{Bid}TV_{t-1}^{\text{Bid}} + \delta \text{Ask}TV_{t-1}^{\text{Ask}} + \sum_{k} \rho_k \text{Bid}D_k
\]

The dependent variable \( UV_t \) is the normalised order volume of the \( t \)th undisclosed order entered:

\[
UV_t = \ln \left( \frac{\text{UndisVol}_t}{V_{\text{daily}}} \right)
\]

\( UV'_{t-1} \) and \( UV'_{t-2} \) are the first two orders of autoregressive (AR) term, while \( e_{t-1} \) and \( e_{t-2} \) are the first two orders of moving average (MA) term. \( \Delta L \) represents the change in liquidity as calculated in Equation (5). \( TV_{t-1}^{\text{Ask}} \) and \( TV_{t-1}^{\text{Bid}} \) are the normalised cumulated volume of
undisclosed orders as calculated in Equation (6) and (7). The parameters of equation (8) are estimated with results provided in the next section.

4. Estimation Results

The empirical estimation is implemented for three major Australian stocks that are considered to be most frequently traded in terms of undisclosed orders. They are TLS (telecommunications), BHP (resources) and NAB (banking) all listed on the Australian Stock Exchange.

4.1 ADF Test for Stationarity

As time series studies require that all variables have to be stationary to assure the validity of conventional statistical tests, unit root tests are first applied to test the order of integration of the data. Table 2 presents the results of the Augmented Dickey-Fuller (ADF) tests for a unit root. The ADF tests have null hypothesis that the series is non-stationary with a unit root. Different lag lengths are chosen based on the number of observations obtained for each stock. The ADF t-statistic for all variables indicates a rejection of the null of non-stationarity, with most of the coefficients being significant at 99% confident level.

Table 2: Augmented Dickey-Fuller Unit Root Test on Variables

<table>
<thead>
<tr>
<th></th>
<th>TLS</th>
<th>BHP</th>
<th>NAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$UV_t$</td>
<td>-5.39***</td>
<td>-3.91***</td>
<td>-3.95***</td>
</tr>
<tr>
<td>$UV'_{t-1}$</td>
<td>-5.21***</td>
<td>-3.31**</td>
<td>-3.59***</td>
</tr>
<tr>
<td>$UV'_{t-2}$</td>
<td>-5.44***</td>
<td>-3.01**</td>
<td>-3.45***</td>
</tr>
<tr>
<td>$V_{t-1} / V_{t-2}$</td>
<td>-4.19***</td>
<td>-4.29***</td>
<td>-2.81*</td>
</tr>
<tr>
<td>$CV_{Bd}$</td>
<td>-4.01***</td>
<td>-3.36**</td>
<td>-3.18**</td>
</tr>
<tr>
<td>$CV_{Ask}$</td>
<td>-4.44***</td>
<td>-5.23***</td>
<td>-3.60***</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p_{min}</td>
<td>$</td>
<td>-6.31***</td>
</tr>
<tr>
<td>$</td>
<td>\Delta p_{close}</td>
<td>$</td>
<td>-4.54***</td>
</tr>
</tbody>
</table>

Critical Values for the rejection of null hypothesis:

<table>
<thead>
<tr>
<th>Level</th>
<th>TLS</th>
<th>BHP</th>
<th>NAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>-3.45</td>
<td>-3.54</td>
<td>-3.56</td>
</tr>
<tr>
<td>5%</td>
<td>-2.87</td>
<td>-2.91</td>
<td>-2.92</td>
</tr>
<tr>
<td>10%</td>
<td>-2.57</td>
<td>-2.59</td>
<td>-2.60</td>
</tr>
</tbody>
</table>

Notes: the table presents the ADF statistics with intercept and not trend as well as the associated Mackinnon (1991) critical values for all variables of three stocks, with a significant level of 90% expressed by ***, 95% expressed by ** and 99% expressed by *. A different number of lags is chosen for each stock based on the number of observations, TLS: 4 lags, BHP: 2 lags and NAB: 1 lag.
4.2 Results from the ARMA Model

The estimation results from the ARMA model in Equation (8) for the three stocks are presented in Table 3 with $R^2$ statistics and residual tests of autocorrelation and Heteroscedasticity also reported. First, it is noticed that the two modified autoregressive lags are strongly statistically significant at a 95% confident level for all stocks, and the first moving averages lag is significant for two stocks. This means that the past orders' size is explanatory in terms of the size of the current order submitted by the same broker. This provides evidence that even with undisclosed orders, brokers also use a series of medium sized orders rather than one big size order to buy or sell a stock. It conforms with our assumption that when trading with undisclosed orders, brokers also prefer to break their large orders into several smaller size ones. This conforms with the empirical findings of Barclay and Warner (1993) and their “stealth trading” hypothesis.

Second, the absolute price change variables that represent short-term and long-term price volatility make a varying contribution to the sample stocks. The absolute price change 5 minutes prior to the submission, $|\Delta p_{5\text{min}}|$, is statistically significant in the explanation of the order size for NAB, but it fails to explain the variation in order size for BHP. The coefficient $\theta$ for long-term absolute price change has a negative sign, implying a negative dependence of undisclosed order size and the long-term price volatility. Berkman (1996) argues that limit orders are fully displayed to provide free options to other market participants, and the undisclosed limit orders reduce the value of free options. Aitken, Berkman and Mak (2001) reported that the option value of limit orders, and thus the use of undisclosed orders that reduces this option value, is expected to increase in volatility. Our finding is consistent with this positive relationship between the reduction of option value and volatility only on a short-term basis. However, neither of these two volatility measures provide significant explanatory power for the order size for TLS, instead, the change of liquidity, $\Delta L$, is shown to be significant for this stock.

Third, the cumulative trading volume in undisclosed orders during the past 5 days on either side significantly contributes to the variation of the order size for all three stocks. This suggests that the undisclosed order submission is likely to be part of an informed trading process, given that the large undisclosed trading volume in the past five days affects the size of current undisclosed order. The time-of-the-day effect only has a significant impact on one of the three stocks.
Table 3: Estimation Results of the ARMA Model for TLS, BHP and NAB

<table>
<thead>
<tr>
<th></th>
<th>TLS</th>
<th></th>
<th>BHP</th>
<th></th>
<th>NAB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>Std. Error</td>
<td>Coefficient</td>
<td>Std. Error</td>
<td>Coefficient</td>
<td>Std. Error</td>
</tr>
<tr>
<td>c</td>
<td>-1.836***</td>
<td>(0.35)</td>
<td>-2.667**</td>
<td>(1.14)</td>
<td>-1.168</td>
<td>(0.99)</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.464***</td>
<td>(0.06)</td>
<td>0.323**</td>
<td>(0.16)</td>
<td>0.577**</td>
<td>(0.12)</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.251***</td>
<td>(0.06)</td>
<td>0.321**</td>
<td>(0.14)</td>
<td>0.326**</td>
<td>(0.14)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.070</td>
<td>(0.06)</td>
<td>-0.623***</td>
<td>(0.16)</td>
<td>0.990***</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>-0.081</td>
<td>(0.06)</td>
<td>-0.531***</td>
<td>(0.15)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.182**</td>
<td>(0.07)</td>
<td>0.314</td>
<td>(0.32)</td>
<td>0.130</td>
<td>(0.24)</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>0.314</td>
<td>(0.38)</td>
<td>-</td>
<td>-</td>
<td>3.636**</td>
<td>(1.51)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>-0.051</td>
<td>(0.08)</td>
<td>-0.351</td>
<td>(0.25)</td>
<td>-0.141</td>
<td>(0.13)</td>
</tr>
<tr>
<td>$\delta_{bid}$</td>
<td>-0.047</td>
<td>(0.05)</td>
<td>0.264**</td>
<td>(0.14)</td>
<td>0.292</td>
<td>(0.19)</td>
</tr>
<tr>
<td>$\delta_{ask}$</td>
<td>0.086**</td>
<td>(0.05)</td>
<td>0.132</td>
<td>(0.21)</td>
<td>-0.280***</td>
<td>(0.09)</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>0.058</td>
<td>(0.31)</td>
<td>1.332***</td>
<td>(0.43)</td>
<td>0.313</td>
<td>(0.99)</td>
</tr>
<tr>
<td>$\rho_2$</td>
<td>0.146</td>
<td>(0.19)</td>
<td>0.146</td>
<td>(0.44)</td>
<td>0.278</td>
<td>(0.18)</td>
</tr>
<tr>
<td>$\rho_3$</td>
<td>0.132</td>
<td>(0.18)</td>
<td>1.034***</td>
<td>(0.26)</td>
<td>0.228</td>
<td>(0.21)</td>
</tr>
<tr>
<td>$\rho_4$</td>
<td>0.067</td>
<td>(0.18)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

R-Squared | 55.91% | 50.88% | 76.86% |
Adjusted R-Squared | 53.92% | 45.88% | 70.33% |
Q-Statistic (Residuals) | 5.024 (54.1%) | 7.196 (30.3%) | 7.430 (38.5%) |
Q-Statistic (Squared Residuals) | 4.910 (55.5%) | 4.461 (61.5%) | 2.069 (95.6%) |

Notes: the table presents estimation results for equation (8):

$$U_{t} = c + \alpha_1 U_{t-1} + \alpha_2 U_{t-2} + \beta_1 \epsilon_{t-1} + \beta_2 \epsilon_{t-2} + \gamma \Delta L + \varphi | \Delta p_{low} | + \theta | \Delta p_{close} | + \delta_{bid} T V_{t}^{bid} + \delta_{ask} T V_{t}^{ask} + \sum_{k=1}^{4} \rho_k D_k$$

where the second last row reports the Ljung-Box Q-statistics and their p-values at lag 5 that tests statistic for the null hypothesis that there is no autocorrelation up to order 5. The last row shows the adjusted $R^2$ values as a supplementation to the $R^2$. The adjusted $R^2$ is computed as: $1 - \left( 1 - R^2 \right) \left( \frac{T-1}{T-k} \right)$.

As far as the goodness of fit statistics are concerned, the $R^2$ and the adjusted $R^2$ are provided at the bottom part of Table 3. The $R^2$ measures the success of the regression in predicting the values of the dependent variable within the sample. It is the fraction of the variance of the dependent variable explained by the independent variables. The results in Table 3 show that the $R^2$ statistic of the ARMA model is generally satisfying for all three stocks. For instance, NAB has a goodness of fit of about 77%, implying that the model has explained 77% of the variation in the dependent variable.

However, one problem with using $R^2$ as a measure of goodness of fit is that it will never decrease as more independent variables are added. The adjusted $R^2$, denoted as $\overline{R^2}$, penalizes the $R^2$ for the addition of independent variables that do not contribute to the explanatory
power of the model, so the $\bar{R}^2$ is never larger than the $R^2$. The variables are included in the model estimation based on the criterion that the inclusion of each variable increases $\bar{R}^2$. For example, as it is found that the inclusion of the second lag of the MA term ($\epsilon_{t-2}$) in stock NAB decreases the value of $\bar{R}^2$ (though it increases the value of $R^2$), this variable is not used in estimating parameters for stock NAB. Similarly, the fourth time-of-the-day dummy variable is not included in the estimation of BHP and NAB because the addition of it decreases $\bar{R}^2$ in these two stocks. With the problem of redundant variables solved, the adjusted $\bar{R}^2$ for all three stocks remains 70% for NAB, 54% for TLS and 46% for BHP, which verifies the ability of the ARMA model and all independent variables to explain the variability of the dependent variable – the size of undisclosed orders.

Finally, to test the specification of the model and the validity of the coefficients estimated, in the last two rows of Table 3 the Ljung-Box Q-statistics of the residual series and the squared residuals are presented with their p-values in parentheses. The Q-statistic at lag $k$ is a test statistic for the null hypothesis that there is no autocorrelation up to order $k$. For all three stocks, we fail to reject the null up to order 8 for residual series and squared residuals. This implies that there is no serial correlation or Heteroscedasticity (ARCH effects) in the residual series of the ARMA model.

5. Conclusion

Stock Exchanges that adopt electronic order book systems rely on limit orders as a major source of liquidity. Under such an automatic order matching system traders are encouraged to show their order information to attract other market participants. However, the traders who submit limit orders are exposed to various risks and disadvantages, especially when the order volume of concern is large. To help traders control for their order exposure, some markets, for example, the ASX, give traders the option to hide the quantity of their limit orders, provided that the total value of the order is beyond a threshold. In an ARMA framework, this paper focusses on investigating the features of this type of limited orders, identifying the factors that affect the size of them, and examining the trading behaviour of investors in using undisclosed orders as an alternative trading means on the equity market.

The findings of this paper suggest that both price volatility and the change in liquidity have an impact on the size of the undisclosed order submitted. But the degree of contribution
of these factors may vary from one stock to another. The use of the undisclosed orders increases in short-term volatility across stocks, but this is not the case for the long-term horizon. The size of undisclosed orders submitted is affected by the large trading volume on either side in the past 5 trading days before the order submission, suggesting that the submission of undisclosed orders is related to informed trading. Therefore, the appearance of an undisclosed order in a stock may provide a signal of the possibility that there is a new information event on the market.

More importantly, this paper has also shed light on the behaviour of brokers in submitting undisclosed orders. Chan and Lakonishok (1995) suggest that rather than put it directly into the market as a whole, block traders and institutional investors prefer to break up a large order into a series of medium size orders and trade them in a sequence of time. If they use the same strategy when using undisclosed orders, then the orders submitted by the same broker during the sequence of trading should be found correlated. Given the substantially significant coefficients of AR and MA lags in the model, we can see strong correlation between the size of the undisclosed orders submitted by the same broker, providing evidence to support the ‘package trading’ hypothesis for undisclosed orders. Therefore, No matter whether the concern is with disclosed or undisclosed limit orders, block traders always prefer to break up a large order into several moderate size orders and then submit them in a sequence of time.

Owing to the restraints in data availability, especially the broker id used to identify the brokers, the investigation of stock brokers’ behaviour in using undisclosed orders is still at an early stage. This paper has only considered three Australian stocks; it would be interesting to extend this research to a bigger sample of stocks, and to other stock markets.
Notes


2. See Harris and Hasbrouck (1996) for more details in this respect.


5. See Jones, Kaul and Lipson (1994).

References


Madhavan, A., Porter, D. & Weaver, D. 2000, ‘Should Securities Markets Be Transparent?’, *working paper*, University of Southern California.

