Some evidence on the Information Content of Undisclosed Limit Orders on the ASX

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Abstract: This paper is concerned with investigating the information content of undisclosed limit orders, identifying factors that affect their sizes, and examining brokers' behavior in using undisclosed orders.Our estimation results from a sample stocks listed on the ASX indicate that the size of undisclosed orders are affected by a number of factors. Given the 'stealth trading' pattern observed in large disclosed limit orders, this paper provides evidence to support a similar pattern in the case of undisclosed limit orders as well. Our model also provides a statistical measure for estimating the size of undisclosed orders.

***Keywords**: Undisclosed Limit Orders, ARMA model, Liquidity, Volatility*

1. INTRODUCTION

With 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 way from the current market price. 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 and empirical level. The other important feature of a trading system is market transparency, 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 has 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. Madhavan (1995) argues that block trade brokers 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, stock exchanges must encourage liquidity suppliers (traders who offer liquidity to the market) to publicly display their limit orders so that liquidity demanders can be attracted. 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. Therefore, while enhancing their market transparency of limit orders for liquidity offer, order-driven system exchanges have to compile 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. 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 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. The behaviour of block traders has been the focus of many authors. Recent studies of Chan and Lakonishok (1995) have found evidence that block traders and 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 block 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. If the total value of the order is above a level of the undisclosed order threshold, brokers have the option to hide their quantity. 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.

Our data sets are obtained from (SIRCA), the Security Industry Research Centre of Asia-Pacific, including the order book information such as order initiator, price, disclosed and undisclosed quantity, time of entry, and brokers' ID for a sample period of three months from 4/12/00 to 26/2/01. The orders that contain undisclosed quantities are extract from our sample to form a sub-sample, which is sample data used in this study. After this filtering approximately 2500 observations are included in our new 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 and 15:30 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 excessive autocorrelation in the data sets.

For illustration purpose, we choose three liquid stocks listed on the ASX that have the greatest number of undisclosed orders entered and do not go ex-dividend during the sample period: BHP from mining, NAB from banking and TLS from telecommunications. Table 1 below gives the order details of these stocks.

Table 1. Descriptive Statistics of Undisclosed Volume and Price

	BHP		NAB		TLS	
Buying:						
	Undiscl. Size (000)	As % of Daily Vol.	Undiscl. Size (000)	As % of Daily Vol.	Undiscl. Size (000)	As % of Daily Vol.
Mean	52.79	1.20	23.97	0.85	229.01	1.29
Min.	5.83	0.13	3,500	0.12	14.30	0.08
Max.	500.00	11.34	200.00	7.12	1,100.00	6.20
Std.Dev	73.16		34.64		216.88	
Selling:						
	Undis. Size (000)	As % of DVol	Undis. Size (000)	As % of DVol	Undis. Size (000)	As % of DVol
Mean	63.04	1.43	53.85	1.92	154.10	0.87
Min.	5.00	0.11	3.50	0.12	14.44	0.08
Max.	500.00	11.34	500.00	17.81	3,000.00	16.91
Std.Dev	106,34		97.23		253.72	
Daily Vol:	4,409,763		2,807,871		17,737,877	

On the buying side as shown in the first panel of Table 1, TLS has the largest mean size of the undisclosed orders that is approximately 230,000 shares, 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 undisclosed orders 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 orders are used more often on selling NAB than purchasing it. On the contrary, TLS has a mean size that only accounts for 0.87% of its daily trading volume on selling side as opposed to 1.3% on purchasing side. This suggests that for TLS undisclosed orders are more often used in purchasing than selling.

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. For order level data, the trading volume is simply order size. Therefore, the potential impact of volatility on the size of undisclosed orders can be captured by a short-term price volatility measured as the absolute price change from the last five minutes before order submission, $|\text{Ln}\,(P_i / P_{5min})|$, and a long-term price volatility measured as the absolute price change from yesterday's close price, $|\text{Ln}\,(P_i / P_{close})|$. 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 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 is 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 before an undisclosed order is submitted. This is an important factor that affects 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 in market. This ratio of change in liquidity is expressed in equation (3) as:

$$\Delta L = \frac{\text{Trading Volume up at tx of the day}}{\text{Average Trading Volume at tx over 30 days}} = \frac{V_x}{\bar{V}_x} \quad (3).$$

As a supplement, the total volume of undisclosed orders entered from bid (UZ_t^{bid}) and ask (UZ_t^{ask}) side during the last 5 trading days before entering the current undisclosed order are also computed to test the existence of market information in a relatively longer term. Easley and O'Hara (1987) argue that the informed traders always tend to trade in large volume. So if the total quantity of undisclosed orders submitted on either side in the past five trading days is exceptionally large, it indicates that there has been new public information or informed trading in this stock lately. These two variables are normalised by the stock's average daily trading volume before being included in the model,

$$TV_t^{bid} = Ln\left(\frac{\sum UZ_t^{bid}}{\overline{V}_{daily}}\right) \qquad (4)$$

$$TV_t^{ask} = Ln\left(\frac{\sum Vol_t^{ask}}{\overline{V}_{daily}}\right) \qquad (5)$$

As we use intra-day data at order level, the price and volume measures suggest certain patterns during different time of the day. Wood, Mclinsh and Ord (1985) find an asymmetric *U*-shaped pattern in price series, and Chan Christie and Schultz (1995) observe a similar pattern in trading volume. To eliminate this diurnal effect, the time-of-the-day dummies are computed based on the number of shares submitted in undisclosed orders as a percentage of the average daily trading volume of the stock. First, as in our sample we only have records for undisclosed orders, so at each order i, i=*1, 2,…, n*, we calculate the total number of shares entered from order one to *i* as a percentage of the stock's average daily trading volume. This percentage increases every time when the next data point is included. Then four dummy variables of time-of-the-day can be defined that differentiate the time when the total number of the undisclosed orders account for 30%, 40%, 50% and 60% of the stock's daily volume, respectively. For example, if it is the case that by 10:37:04 am 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 day to that time have dummy1 equal to one, whilst the value of the other three dummies equal to zero. The other three dummy variables are identified in the similar manner.

It is natural to see that block traders have been the frequent users of undisclosed orders. A great deal of research has examined this type of traders' behaviour in submitting large sized disclosed limit orders. It is commonly found that, in order to either avoid high market impact costs, or hide their information advantage, these brokers often break up a large order into a series of moderate size orders. Barclay and Warner (1993) propose a "stealth trading" hypothesis and conclude that medium size trades drive price movements the most. However, lot of times block trades submit undisclosed orders, and their behaviour in submitting undisclosed orders is yet to be investigated. It is suspected that these orders might also be technically broken up into a series of smaller sized ones. If brokers use the same strategy to submit undisclosed orders, then the undisclosed orders submitted consecutively by the same broker will be somehow correlated. Therefore, an autoregressive moving average (ARMA) framework is applicable in this case to determine the size of the next undisclosed order from the size dependence. 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 assumption that the broken-up orders of the same broker are likely to be correlated, the AR terms in the model are chosen to be the lagged undisclosed orders submitted by the ***same broker*** who enters the current undisclosed order. 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,… t_n, then orders submitted at t_{n-i}, ($i=1, 2, …, n-1$) 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 that incorporates all above-described factors: the price volatility, the liquidity, the existence of new information, the time of the day and the stockbrokers' behaviour, is presented in Equation (6):

$$\begin{aligned} UV_t &= c + \alpha_1 UV'_{t-1} + \alpha_2 UV'_{t-2} + \beta_1\varepsilon_{t-1} + \beta_2\varepsilon_{t-2} \\ &+ \gamma\Delta L + \varphi\,|\,Ln(p_t / p_{5\min})\,| + \theta\,|\,Ln(p_t / p_{close})\,| + \\ &\delta^{bid} TV_t^{bid} + \delta^{ask} TV_t^{ask} + \sum_{k=1}^{4}\rho_k^{bid} D_k \end{aligned} \qquad (6)$$

The dependent variable UV_t is the normalised order volume of the *t*th undisclosed order entered:

$$UV_t = Ln(Undis.Vol_t / \overline{V}_{daily}) \qquad (7).$$

UV'_{t-1} and UV'_{t-2} are the first two orders of autoregressive (AR) term, while ε_{t-1} and ε_{t-2} are the first two orders of moving average (MA) term. The other variables are calculated in Equation (1)-(5).

4. THE ESTIMATION RESULTS

The empirical estimation is implemented for three major Australian stocks that are frequently traded in undisclosed orders. 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 *t*-statistic for all variables indicates a rejection of the null of non-stationarity, with most of the coefficients being significant at 95% confident level.

Table 2. Augmented Dickey-Fuller Unit Root Tests

	TLS	BHP	NAB
UV_t	-5.39*	-3.91*	-3.95*
UV'_{t-1}	-5.21*	-3.31*	-3.59*
UV'_{t-2}	-5.44*	-3.01*	-3.15*
$V_x / \overline{V}_x$	-4.19*	-4.29*	-2.94*
CV^{Bid}	-4.01*	-3.36*	-3.18*
CV^{Ask}	-4.44*	-5.23*	-3.60*
$\lvert \Delta p_{5min} \rvert$	-6.31*	-4.49*	-3.51*
$\lvert \Delta p_{close} \rvert$	-4.54*	-3.72*	-2.92*

The estimation results from the ARMA model in Equation (6) are presented in Table 3. First, it is noticed that the 2 modified autoregressive lags are statistically significant at a 95% for all stocks, and the first moving averages lag is significant for two stocks. This means that the past order sizes have explanatory power to determine the size of the current order. This provides evidence that when trading with undisclosed orders, brokers also prefer to break up a large size undisclosed order into several smaller size ones. It is confirmed with our early assumption, and provides a supplement to Barclay and Warner (1993)'s "stealth trading" hypothesis on disclosed limit orders.

Second, the cumulative trading volume 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 a part of 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.

Third, comparing with other independent variables, the short-term and long-term price volatility has little effect on the dependent variable, with only the short –term price volatility being significant in NAB. However, it is noted that the coefficient θ for long-term absolute price change is negative, 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 coincides with this positive relation is only short-term based. The change of liquidity, ΔL, is significant for one of three stocks.

Table 3. Estimation Results of the ARMA Model

	TLS	**BHP**	**NAB**
	Coeff.	Coeff.	Coeff.
c	-1.84*	-2.67*	-1.17
α_1	0.46*	0.32*	0.58*
α_2	0.25*	0.32*	0.33*
β_1	0.07	-0.62*	0.99*
β_2	-0.08	-0.53*	-
γ	0.18*	0.31	0.13
φ	0.31	-	3.64*
θ	-0.05	-0.35	-0.14
δ^{Bid}	-0.05	0.26*	0.29
δ^{Ask}	0.09*	0.13	-0.28*
ρ_1	0.06	1.33*	0.31
ρ_2	0.15	0.15	0.28
ρ_3	0.13	1.03*	0.223
ρ_4	0.07	-	-
R^2	55.91%	50.88%	76.86%
$\overline{R}^2$	53.92%	45.88%	70.33%
$Q\text{-}e_i$	5.024 (54.1%)	7.196 (30.3%)	7.430 (38.5%)
$Q\text{-}e_i^2$	4.910 (55.5%)	4.461 (61.5%)	2.069 (95.6%)

At the lower panel of Table 3, the values of R^2 and the adjusted R^2 are presented to test the goodness of fit of the model. The R^2 measures the fraction of the variance of the dependent variable explained by the independent variables, but the value of R^2 will never decrease as more independent variables are added. Therefore, the adjusted R^2, or $\overline{R}^2$, is utilised that penalizes the R^2 for the addition of independent variables that do not contribute to the explanatory power of the model. The adjusted $\overline{R}^2$ for all stocks are ranged from 46-70%, indicating a strong ability our independent variables to explain the size of undisclosed orders in an ARMA framework.

Finally, to test the efficiency of the coefficients and model specification, the Ljung-Box Q-statistics of the residual series and the squared residuals are also computed 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 at lag 8 for residual series and squared residuals.

5. CONCLUSION

To help traders control for their order exposure in order driven markets, some stock exchanges give traders option to hide the quantity of their limit orders. In an ARMA framework, this paper focuses on investigating features of this type of limited orders, identifying the factors that affect the size of them, and examining the trading behaviour of brokers who are regular users of this type of orders.

Chan and Lakonishok (1995) suggest block traders always prefer to break up a large disclosed limit order into a series of smaller size orders and trade them in a sequence of time. The finding of this paper provides empirical evidence that the similar trading strategy prevails with undisclosed orders. This study thus provides a supplement to Barclay and Warner (1993) that the "stealth trading" hypothesis is supported not only by disclosed orders, but also undisclosed orders. Moreover, the strong order size dependence in 'package trading' enables us to predict the size of undisclosed orders from previous trades combined with other liquidity and volatility variables.

6. REFERENCES

Aitken, M., P. Brown, and T. Walter, Infrequent Trading and Firm Size as Explanations for the Intra-Day Patterns in Returns on SEATS, Working Paper Series, SIRCA, 1996.

Aitken, M., H. Berkman and D. Mak, The Use of Undisclosed Limit Orders on the Australian Stock Exchange, *Journal of Banking and Finance*, 25, 1589-1603, 2001.

Berkman, H., Large Option Trades, Market Makers, and Limit Orders , *Review of Financial Studies*, 9, 977-1002, 1996.

Biais, B., Price Formation And Equilibrium Liquidity in Fragmented and Centralized Markets, *Journal of Finance*, 48, 157-184, 1993.

Chan, L. and J. Lakonishok, The Behavior of Stock Prices Around Institutional Trades, *Journal of Finance*, 50, 1147-1174, 1995.

Chan, C., W. Christie and P. Schultz, Market Structure and the Intra-ay Pattern of the bid-Ask Spreads for NASDAQ Securities, *Journal of Business*, 68, 35-60, 1995.

Hondt, C. Winne, R. and A. Francois-Heude, Hidden Orders: An Empirical Study on the French Segment of Euro.NM, Working Paper Series, Facultés Universités Catholiques de Mons, 2001.

Easley, D. and M. O'Hara, Price, Trade Size, and Information in Securities Markets, *Journal of Financial Economics*, 19, 69-90, 1987.

Easley, D. and M. O'Hara, Time and the Process of Security Price Adjustment, *Journal of Finance*, 47, 577-605, 1992.

Engle, R. and J. Russell, Autoregressive Conditional Duration: A New Model for Irregularly Space Transaction Data, *Econometrica*, 66, 1127-1162, 1998.

Harris, L. 1997, 'Order Exposure and Parasitic Traders', *Working Paper*, Marshall School of Business, University of Southern California.

Harris, L. & Hasbrouck J. 1996, 'Market vs. Limit Orders: The Super DOT Evidence on Order Submission Strategy', *Journal of Financial and Quantitative* Analysis, vol. 31, pp. 213-232.

Keim, B. and A. Madhavan, Anatomy of the Trading Process: Empirical Evidence on the Behaviour of Institutional Traders, *Journal of Financial Economics*, 37, 371-398, 1995.

Lyons, R., Optimal Transparency in a Dealership Market with an Application to Foreign Exchange, Working Paper Series, University of California, Berkley, 1994.

Madhavan, A., Consolidation, Fragmentation and the Disclosure of Trading Information, *The Review of Financial Studies*, 8, 579-603, 1995.

Madhavan, A., Security Prices and Market Transparency, *Journal of Financial Intermediation*, 5, 255-283, 1996.

Wood, A., McInish, T. and J. Ord, An Investigation of Transactions Data for NYSE Stocks, *Journal of Finance*, 40, 723-741, 1985.