Limit Order Book Transparency, Execution Risk and Market Liquidity

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Abstract

This paper provides new evidence on the effect of limit order book disclosure on trading behaviour. We examine the natural experiment affected by the Sydney Futures Exchange in January 2001 when it increased limit order book disclosure from the depth at the best bid and ask prices to depth at the three best bid and ask prices. We find evidence consistent with a change in trading behaviour coinciding with the increase in pre-trade transparency. Consistent with predictions of a theoretical model based on execution risk, we find a statistically significant decline in depth at the best quotes. There is no evidence of a significant change in spreads. Further, the proportion of market orders exceeding depth at the best quotes increases in a transparent limit order book reflecting a reduction in execution risk. These results are consistent with the proposition that market order traders pay a premium to limit order traders for execution certainty in a transparent market.

1. Introduction

This paper examines the impact of disclosing market depth information in the limit order book on market behaviour. Securities markets worldwide differ in their disclosure of pre-trade information. The London Stock Exchange (LSE), Singapore Stock Exchange (SGX) and Australian Stock Exchange (ASX) disclose their entire limit order books to investors and can therefore be described as highly pre-trade transparent.[1] In contrast, the Toronto Stock Exchange (TSE) and Hong Kong Stock Exchange (HKEX) restrict disclosure to the best five bid and ask prices and aggregate order volume while the Swiss Exchange (SWX) employs the least pre-trade transparent regime, revealing only the best bid and ask prices. In the last 15 years, a number of markets have moved towards disseminating more information in the limit order book to investors. In 1990 the TSE instituted a computerised trading system called Market by Price (MBP) which enabled an increase in disclosure from the best quotes to the five best prices and order volume. More recently, the NYSE introduced Open Book in 2002, which displays a snapshot of all price steps and associated depth in the limit order book at ten second intervals. The Nasdaq stock market al.so enabled access to more order book information in 2002 via the introduction of their SuperMontage trading system.[2]

The trend towards increased pre-trade transparency appears to be encouraged by securities market regulators. For example, the US Securities and Exchange Commission (SEC, 1994) and UK Office of Fair Trading (Carsberg, 1994) believe that greater pre-trade transparency will enhance liquidity and specifically market depth.[3] This viewpoint is consistent with the rapid growth of off-exchange trading on Electronic Communication Entwork's (ECN's) which is presumed to be driven in part

by the high level of order flow information available on these systems [see Lehmann and Modest (1994) and Simaan et al. (2003)].[4] It also figures prominently in the debate surrounding the automation of securities markets, which may offer a higher level of pre-trade transparency than floor traded systems [see Madhavan (1996)], and the efficiency of auction versus dealer markets, where auction markets typically operate electronic limit order book schedules [see Pagano and Roell (1996)].

Competition amongst securities markets for order flow, regulatory interest in transparency and changes to pre-trade (quote or limit order) and post-trade (trade reporting) disclosure practices by securities markets has led to a growing academic interest in the issue. Early studies, including Madhavan (1992), Biais (1993) and Pagano and Roell (1996), develop theoretical models comparing different market structures with differing levels of pre-trade and post-trade transparency. Changes to block trade publication rules on the LSE provided the first natural experiment of a transparency regime change. Both Gemmill (1996) and Board and Sutcliffe (2000) find that delayed trade publication, representing a decrease in post-trade transparency, has no impact on market liquidity.[5] Laboratory experiments executed by Bloomfield and O'Hara (1999) and Flood et al. (1999) also test the impact of trade and quote disclosure in multiple dealer markets on elements of market quality.[6] Bloomfield and O'Hara (1999) find that trade and quote disclosure improves liquidity at the expense of price efficiency while Flood et al. (1999) find the opposite result.[7] More recently, the use of hidden limit orders as a means of reducing pre-trade transparency is examined by Anand and Weaver (2003), who find no evidence of a change in spreads, execution costs or visible depth around their introduction on the TSE.

Two recent studies focus specifically on the issue of disclosing market depth information in the limit order book. Madhavan et al. (2000) and Baruch (2003) construct theoretical models to address the question of how revealing the content of the limit order book to all traders in a market affects elements of market quality. Madhavan et al. (2000) find that disclosing the contents of the limit order book will result in a decrease in liquidity, as measured by market depth and the price impact of trades. A transparent market is hypothesized to enable more profitable order placement by market order traders resulting in a withdrawal of limit orders, by liquidity suppliers, to reduce losses. In contrast, Baruch (2003) finds that in a specialist market, disclosure would improve liquidity as measured by the price impact of market orders. In this model, publication of the order book eliminates informational advantage causing greater competition amongst strategic limit order traders, and amongst limit order traders and the specialist, resulting in improved liquidity and more informative prices. The empirical evidence is also conflicting. Madhavan et al. (2000) document a reduction in liquidity on the TSE following the increase in order book disclosure, providing support for their theoretical predictions. The authors report an increase in quoted and effective spreads, reduction in depth at the best quotes and an increase in volatility. In contrast, however, Boehmer et al. (2004) document a reduction in effective spreads on the NYSE following the introduction of Open Book, consistent with an increase in market liquidity. In light of this volume of conflicting evidence, Boehmer et al. (2004) call for further research on the impact of changes in limit order book transparency.

The increase in limit order book disclosure on the Sydney Futures Exchange (SFE) provides an ideal and rare natural experiment to study the effects of a change in pre-

trade transparency. Trade on the SFE currently occurs via a computerised electronic limit order book based on price and then time priority, the Sydney Computerised Market (SYCOM).[8] SYCOM replaced the previous open outcry market modeled on the CME with an automated screen traded market in 1999.[9] Initially the SFE disclosed only the best bid and ask prices and aggregate depth at these prices via SYCOM. On January 22, 2001, for the stock index contracts and January 29, 2001 for interest rate contracts, the SFE began disseminating the best three bid and ask prices and aggregate order volume at those prices to market participants.

We begin our analysis by developing some theoretical rationale to provide testable predictions on the impact of increased limit order book disclosure on trader behaviour and the subsequent effects on depth in the limit order book. This paper extends the previous literature in three main ways. First, the increase in pre-trade transparency on the SFE represents an exogenous increase in limit order book disclosure affecting all participants in the market uniformly. Prior empirical examinations of limit order book transparency are contaminated in the sense that certain participants [specialists and floor traders in Boehmer et al. (2004) and brokers in Madhavan et al. (2000)] already had access to the complete order book information before the changes studied. Such traders with privileged access to the order book can communicate information regarding its content to other market participants [see Baruch (2003)]. Second, this study represents the first examination of limit order book transparency where trading is conducted solely in an automated limit order book. Both prior empirical studies are complicated by a floor traded market operating in tandem with an electronic limit order book. In a limit order book market, depth can be measured precisely, whereas in a hybrid market orders held by floor brokers and specialists willingness to provide liquidity behind posted quotes are not observable. Finally, both Schwert (1981) and

Madhavan et al. (2000) identify the risk inherent in attributing any effects on market quality to a microstructural change when only a single or small number of events have been examined. This paper addresses this limitation by providing additional evidence on the impact of disclosing market depth information in the limit order book on market quality.

The remainder of this paper is structured as follows. Section 2 provides a theoretical model and presents empirical hypothesis to be examined. Section 3 describes the data set employed in the study, and the research design. Section 4 presents the results, and Section 5 provides a summary and conclusion.

2. Theory

Previous theoretical literature examining the effects of disclosing market depth information in the limit order book is confined to models of hybrid auction-dealer markets. Baruch (2003) features a limit order book, call auction market designed to resemble the single price call-type market operating at the open of trading and during trading halts on the NYSE. Madhavan et al. (2000) provide a model of a hybrid auction-dealer market similar to that operating during continuous trading on the NYSE and for the trading of floor stocks on the TSE. Both models feature a strategic specialist or designated dealer who has privileged access to the order book prior to the increase in pre-trade transparency and are therefore not strictly applicable to the setting examined in this study.

The SFE operates a purely electronic limit order book market without the presence designated dealers or market makers for its major contracts.[10] In addition, no individual or group of individuals had privileged access to order flow prior to the change in transparency. This market setting therefore requires the development of a new conceptual framework which accounts for a uniform increase in transparency across market participants. In this section, we develop some theoretical rationale to predict the effect of increasing the transparency of the limit order book on trading behaviour, including depth and bid-ask spreads – two common measures of liquidity.

Consider a limit order book containing bid and ask quotes at different price levels and their associated order sizes. Assume that on either side of the book there are only three quoted price levels, p_1, p_2, p_3, where p_1 is the best quote and p_2 the second best. For bid quotes $p_1>p_2>p_3$ and for asks $p_1<p_2<p_3$. The distance separating consecutive

prices (the minimum tick size) is taken as fixed and exogenous to the model. Aggregate market depth is defined by the total volume of orders in the order book at the prices shown.

Two visible forms of the order book are considered. The first lacks an important element of transparency in that traders can see only the best quoted price p_1 and the volume of orders at that price. Market depth beyond the best quotes is therefore unobservable. This is compared with a more transparent order book, where traders can see all three prices and their associated volumes. The theoretical issue addressed here is how the probability (frequency) distribution of orders over p_1, p_2 and p_3 will change when the market shifts from showing depth only at p_1 to p_1, p_2 and p_3.

Consider a trader who wishes to fill a market order of some given size larger than the volume available at p_1 (but less than total available volume at any price p_1, p_2 or p_3). When the trader can see market depth only at only p_1, any market order size greater is risky. It may be that there is zero volume available at p_2, in which case the remainder of the market order will be filled at the least favorable price p_3.

The trader is therefore faced with a decision problem. Either he risks an unknown average price by ordering more than the volume showing at p_1 or he incurs a bundle of related search costs[11], including perhaps most importantly the added cost of completing his order in a market informed of his arrival and motivation by his initial clearance of the total volume showing at p_1. Whichever of the two possible execution strategies the trader follows, the expected average price (per unit) achieved in a non-transparent market over the total required order size is a random variable:

$$\lambda_1 p_1 + E\left[\lambda_2 p_2 + \lambda_3 p_3\right],$$

where λ_i is the proportion of the total order transacted at price p_i (i=1,2,3) and λ_2 and λ_3 are unknowns ($\lambda_1+\lambda_2+\lambda_3=1$).[12]

Now consider a fully transparent market, where by definition the average price of a market order is, with certainty:

$$\pi_1 p_1 + \pi_2 p_2 + \pi_3 p_3,$$

where π_i is the known proportion of the total order transacted at fixed price p_i (i=1,2,3) ($\pi_1+\pi_2+\pi_3=1$). We predict that risk averse traders placing market orders will trade at a less favorable expected (average) price when that price is certain than when it is risky. That is, for market sell orders:

$$\lambda_1 p_1 + E\left[\lambda_2 p_2 + \lambda_3 p_3\right] > \pi_1 p_1 + \pi_2 p_2 + \pi_3 p_3,$$

and *vice versa* for market buy orders. Sellers will rationally expect a lower average price, and buyers a higher average price, when this price is executed with certainty than when it is a random variable. In other words, *expected return is lower* for sellers submitting market orders in an environment where execution *risk is lower*. The flip side of this argument is that limit order traders, who show more of their hand under a

transparent market and therefore provide greater certainty to market order traders, are rewarded with a better average price.

The difference between the certain price available to market order traders in a transparent market and the expected price offered in a less transparent market is the premium imposed by the market (i.e by limit order traders) in exchange for certainty. This premium is evident in the limit order book when *ceteris paribus* either (or both) $\pi_1<\lambda_1$ or $\pi_2<\lambda_2$, meaning that less volume is available at a given price level when market depth at the next best price is transparent than when it is unobservable.

The more pronounced difference is likely to be a shift of order volume away from the best price p_1 to either p_2 or p_3, since limit order traders who want their orders to show can now order at either p_2 or p_3 when previously they had no choice but to order at p_1. There is no equivalent motivation for a shift from p_2 to p_3. Orders previously at p_2 did not show, but in a transparent market they will show either at p_2 or p_3, making the limit trader indifferent between these two price levels from the perspective of transparency. Hence, the following testable hypothesis:

H_1: Average market depth at the best available quote is less when traders are informed of market depth at the next best quoted prices.

It remains to consider the effect of transparency on spreads. Although some proportion of limit order traders can be expected to shift their orders away from p_1 when order volume shows at p_2 and p_3, thus reducing average depth at the best price, there is no reason to expect that all limit order traders will do so. It is plausible that the marginal limit order trader will continue under most conditions, if not always, to

order at p_1, thereby ensuring the earliest possible trade and maximum liquidity. The effect of transparency at price levels p_2 and p_3 on spreads is therefore uncertain. It can be deduced from the economic model described above only that the average spread will stay the same or perhaps widen a little on average under transparency. Thus:

H_2: Average market spread when traders are informed of order volume at the second (and third) best prices is greater than, or equal to, average spread when volume is revealed only at the best price.

Suppose now that the limit order volumes available at the three prices shown are v_1, v_2, and v_3 respectively. The realized average price of market order trader is then certain up to a total volume of $v_1+v_2+v_3$. Pre-transparency the price risk of a market order increased for every extra unit ordered over and above v_1. Once v_1, v_2, and v_3 become transparent, a risk averse market order trader wishing to fill an order of size greater than v_1 is able to do so without considering risk, and is therefore likely to order more than v_1 more frequently than when the total price of such an order is uncertain. This remains the case even though the certain realized price is (per H_1) greater than the expected price of such an order under a non-transparent market. The risk averse market order trader is ready to pay for certainty in the total realized price, but if v_1 is less under the transparent market than previously, the overall advantage from certainty is realized only by making orders generally larger than v_1, or dong so more often at least, than under a non-transparent market:

H_3: The relative frequency of market order sizes greater than the volume available at the best available quote is greater when traders are informed of market depth at the next best quoted prices.

3. Data and Method

The Reuters data used in this study are provided by SIRCA and are captured in real time from SYCOM. The data extends from September 15, 2000 to June 19, 2001 and straddles the dates that limit order book disclosure changed on the SFE. The data contains records describing every transaction, quote change and change in aggregate limit order volume at each disclosed price step, time stamped to the nearest second.[13] SYCOM data is disseminated instantaneously to quote vendors such as Bloomberg and Reuters. They are provided with only the content of the limit order book shown to traders on SYCOM. The four most actively traded futures contracts on SYCOM are examined. These include the Share Price Index (SPI), Bank Accepted Bills, the Three Year Bond and the Ten Year Bond futures contracts. Consistent with prior event studies in futures markets, we confine our analysis to daytime trading in the near term contract [eg. Bortoli, Frino and Jarnecic (2004), Aitken, Frino and Hill (2004)].

We apply a pre-post research design centered on the change in transparency regime on the Sydney Futures Exchange. Two subsamples of data are examined, one including days for the period when only the *best* bid and ask prices and aggregate order volume are disclosed in the limit order book (the pre-event period) and the other including days when the *three best* bid and ask prices and aggregate order volume at each price step is disclosed (the post-event period). The increase in public disclosure of the limit order book occurs part way through trading in the near term March expiry contract on January 22, 2001 for the SPI futures contract and January 29, 2001 for the interest rate futures contracts. The sampling procedure examines one complete sequence of futures data from a near term futures contract series both before and after the change

in transparency for stock index and interest rate futures contracts. Hence, the pre-event period samples trading activity in the December 2000 contracts, while the post-event period samples trading activity in the June 2001 contracts, both over periods that these contracts were nearest to maturity. Specifically, the pre-event sample period chosen extends from October 2, 2000 to December 29, 2000 for the SPI futures contract and from September 15, 2000 to December 16, 2000 for the interest rate futures contracts. The post-event sample period extends from April 2, 2001 to June 29, 2001 for the SPI futures contract and from March 15, 2001 to June 15, 2001 for the interest rate futures contracts.

The sampling procedure is designed to control for possible time to expiration effects in liquidity [Grammatikos and Saunders (1986)]. The average time to maturity of the contracts for the days sampled in the pre-event period is approximately equal to that of the days sampled in the post-event period [see Frino, Hill and Jarnecic (2000)]. Consistent with Madhavan et al. (2000) the sampling procedures also allows a time delay between the event date and the beginning of the post-event sample period mitigating possible biases from proximity to the event such as a learning effect. The final sample period consists of 123 trading days in the SPI, 126 trading days in the Bank Accepted Bills and 128 trading days in the Three and Ten Year interest rate futures contracts. The data includes 266,510 transactions and 551,581 quote changes in the SPI, 32,159 transactions and 109,203 quote changes in Bank Accepted Bills, 110,987 transactions and 263,350 quote changes in Three Year Bonds and 104,647 transactions and 254,453 quote changes in Ten Year Bonds.

Hypothesis 1 and 2 are tested by examining the change in depth at the best quotes, as well as bid-ask spreads in the pre and post-event samples. Depth and bid-ask spreads are sampled each 20 minutes during the trading day. Depth is defined as the total volume available at the standing best buy and sell quotes in the limit order book at the end of each interval. The standing bid-ask spread in points is also examined. Previous studies examining liquidity in the equities markets analyze spreads across a portfolio of securities and employ a proportional bid-ask spread to control for differences in the minimum tick size across stocks [See McInish and Wood (1992)]. This is unnecessary in the present study since the analysis is confined to a single futures contract series'.[14] A parametric *t*-test is used to compare whether the means of the variables in the pre- and post-event periods are significantly different. A non-parametric Wilcoxon Rank Sum test is applied to determine if there is a shift in the population distributions.

Harris (1994) develops a model which identifies a number of variables that explain changes in depth. It is important to control for changes in these variables in order to ensure that any changes in depth observed in this study are attributable to the change in transparency, and not merely to changes in market conditions which influence these variables. The model below is estimated to test the impact of increased pre-trade transparency on market depth, controlling for possible changes in known determinants;

$$DEPTH_t = a + \beta_1 D_t^L + \beta_2 VOLUME_t + \beta_3 VOLATILITY_t \qquad (1)$$

where the dependent variable $DEPTH_t$ is the logarithm of the daily average limit order volume at the best buy and sell. The log transformation of depth and trading volume

is consistent with Harris (1994). The dummy variable D_t^L is assigned a value of 1 if the observation is drawn from the period where the best three bid-ask price steps and associated aggregate order volume are disclosed, or 0 otherwise. $VOLUME_t$ is the logarithm of total daily traded volume. $VOLATILITY_t$ is measured as the logarithm of the high price divided by the low price in the trading day [see Wiggins (1992)]. All *t*-statistics are adjusted for heteroskedasticity and autocorrelation using the procedure developed by Newey and West (1987).

McInish and Wood (1992) identify trading volume and price volatility as influencing bid-ask spreads. Specifically, they document that bid-ask spreads are negatively related to volume and positively related to price volatility. The regression model presented below is estimated to control for the possibility that changes in broad market conditions may have influenced bid-ask spreads during the sample period;

$$BAS_t = \alpha + \beta_1 D_t^L + \beta_2 Volume_t + \beta_3 Volatility_t \qquad (2)$$

where the dependent variable BAS_t is the logarithm of the daily average bid-ask spread sampled each twenty minutes during the trading day. The explanatory variables are as previously defined for regression model 1. Again, all t-statistics are adjusted for heteroskedasticity and autocorrelation following Newey and West (1987).

Hypothesis 3 predicts that a reduction in execution risk following the increase in transparency of the limit order book is likely to encourage traders to place market orders which execute against limit orders beyond the best quotes. We calculate the number of such orders, and the number of such orders relative to the total number of

transactions. A chi-square test of the difference in proportions is used to determine whether the ratio changed significantly from the pre to post samples.

Trade packages are examined to isolate the impact of the change in transparency on market order execution. This analysis requires the use of a unique register of transactions obtained from the SFE. The data is extracted from OM Secur, the SFE's electronic settlement system and contains fields which document the date, time to the nearest minute, price, volume, contract code, buy or sell code, trader account identifier and broker identifier. Trade packages are constructed using the methodology developed by Chan and Lakonishok (1995). A buy (sell) trade package is defined as a sequence of purchases (sales) by the same trader, consecutively without a 1-day trading break.[15] A parametric *t*-test is used to compare whether the means trade package size in the pre and post-event periods is significantly different. A non-parametric Wilcoxon rank sum test is applied to determine whether the median package size is statistically different.

4. Results

4.1 Tests of Hypothesis 1 and 2

Table 1 provides summary statistics and results from tests of the impact of increased pre-trade transparency on the two liquidity measures, depth and spreads. Panel A of Table 1 reports results for depth at the best quotes. Consistent with Hypothesis 1, Panel A of Table 1 documents a decline in average depth across the four contracts examined. Increased transparency of the limit order book corresponds with a reduction in depth of 9.34 contracts in the SPI, 560.49 contracts in the Bank Accepted Bills, 722.90 contracts in the Three Year Bonds and 60.12 contracts in the Ten Year Bonds. This translates to an economically significant decline in depth of 24.58% for the SPI, 39.26% for Bank Accepted Bills, 37.76% for Three Year Bonds and 34.07% for Ten Year Bonds. Additionally, *t*-tests comparing the means in the pre-event and post-event periods are significant at the 0.01 level for all contracts. The reduction in median depth is similar in magnitude to that shown for average depth and is statistically significant at the 0.01 level using a Wilcoxon rank sum test.

These findings provide preliminary evidence of a deterioration in liquidity following an increase in limit order book disclosure. Consistent with Hypothesis 1 it appears that limit order traders are retracting limit order volume from the best quotes. Although consistent in direction with the results of Madhavan et al. (2000) the magnitude of reductions in depth on the SFE are considerable larger than the modest 2% to 4% reductions reported for the TSE. It is likely that this difference in magnitude is driven by the differences in the operation of the limit order books in each market. In contrast to the SFE, the content of the TSE's limit order book was

already available to exchange members and registered traders. Thus, information pertaining to liquidity beyond the best quotes could be communicated to other market participants, thereby reducing the efficacy of any increase in public limit order book disclosure. Furthermore, the TSE's limit order book market was dedicated to small market capitalization, less liquid issues at the time of the increase in transparency examined. Thus, the market wide impact (the impact across all stocks) of the transparency change could not be evaluated. The bulk of the market, large capitalization and more actively traded stocks, were traded on the TSE's floor where, due to the presence of specialists providing additional liquidity to the limit order book, depth could not be reliably measured.

Panel B of Table 1 reports descriptive statistics for bid-ask spreads. Average bid-ask spreads increase by 0.013068 contract points or 1.24% in the SPI, 0.000128 contract points or 1.14% for Bank Accepted Bills, 0.000115 contract points or 1.14% for Three Year Bonds and 0.000093 contract points or 1.82% for Ten Year Bonds. Consistent with H_2 there appears to be a widening of bid-ask spreads following the increase in pre-trade transparency. However, evidence of a change in bid-ask spreads surrounding the event is not as compelling as that for the change in depth reported in Panel A. The increase in average bid-ask spreads is statistically significant for Three Year Bonds at the 0.01 level and Ten Year Bonds at the 0.05 level. Bank Accepted Bills experience a change in average bid-ask spreads which is significant at the 0.10 level while the SPI contract does not experience a statistically significant increase in bid-ask spreads at conventional levels.

Median bid-ask spreads show a rise for the Three Year and Ten Year Bonds, significant at the 0.01 and 0.05 levels of significance respectively. The SPI and Bank Accepted Bills futures contracts show no change in median bid-ask spreads for up to six decimal places. Further inspection of the sample data reveals that trading is at the minimum tick for 87.76% of observations in the SPI, 95.16% of observations in BAB's, 97.74% of observations in Three Year Bonds and 94.39% of observations in Ten Year Bonds. It is therefore not surprising to see little change in median bid-ask spreads. In summary, consistent with H_2 there is little evidence of a statistically significant change in bid-ask spreads across the futures contracts examined.

Table 2 presents descriptive statistics for the market variables volume and volatility. Panel A of table 1 shows a decrease in mean and median daily contract volume for the SPI in the period following increased limit order book disclosure. The reduction in trading volume is significant at the 0.05 level according to both the *t*-statistic and z-statistics. In contrast, the interest rate futures contracts experience an increase in mean and median daily traded volume, which is significant for Three Year Bonds at the 0.01 level, for Ten Year Bonds at the 0.05 level and insignificant at conventional levels for Bank Accepted Bills. An increase in volatility in the post-event period is also shown across the three interest rate futures contracts. The SPI futures contract experiences no significant change in volatility. These results provide evidence of significant changes in the determinants bid-ask spreads and depth surrounding the change in pre-trade transparency on the SFE. The regression analysis presented below reports the effects of an increase in pre-trade transparency after controlling for changes in volume and volatility.

Table 3 reports the results of regression analysis of depth and bid-ask spreads against the explanatory variables, volume, volatility and a dummy variable for the change in limit order book transparency. Panel A of Table 3 presents the adjusted R^2, F-statistic and estimates of the depth regression parameters, for each of the four contracts examined. The independent variables explain between approximately 25% and 35% of variation in the logarithm of average depth ($DEPTH_t$) depending on the contract examined. This compares to Boehmer et al. (2000) who document adjusted R^2 values of between 5% and 19% for models estimated in the equities market. The F-statistics indicate that the null hypothesis, that the estimated coefficients are all jointly equal to zero, can be rejected at the 0.01 level.

Coefficients on the log of trading volume ($VOLUME_t$) and price volatility ($VOLATILITY_t$) are in the desired direction and significant at the 0.01 level across the four contracts examined. Consistent with Harris (1994) a positive relationship is documented between $DEPTH_t$ and $VOLUME_t$ and a negative relationship is documented between $DEPTH_t$ and $VOLATILITY_t$. Panel A of Table 3 also indicates that after controlling for these known determinants of depth the coefficient on the dummy variable (D_t^L) is negative and significant for all contracts at the 0.01 level. These results are consistent with H_1, that increased limit order book transparency results in a decline in depth, even after controlling for changes in possible determinants of depth. In summary, these results provide further evidence suggestive of a change in the behaviour of limit order traders in response to increased pre-trade transparency. The results imply that limit order traders withdraw depth from the best quotes in response to disclosure of limit order depth beyond the first price step.

Results of the regression analysis on bid-ask spreads is presented in Panel B of Table 3. The explanatory power of the models range between 10% and 46% and are similar in magnitude to those documented by Boehmer et al. (2005) and Madhavan et al. (2002) of between 5% and 58%. The estimated regression models are significant at the 0.01 level, for all contracts, as indicated by the *F*-statistics. Consistent with McInish and Wood (1992), Panel B of Table 3 provides evidence of a negative relationship between bid-ask spreads and volume and a positive relationship between bid-ask spreads and price volatility. The coefficient on $VOLUME_t$ is negative and significant and the coefficient on price $VOLATILITY_t$ is positive and significant, both at the 0.01 level, for the four contracts examined. After controlling for the established determinants of bid-ask spreads, the coefficient on the dummy variable (D_t^L) is positive for the four contracts consistent with H_2. However, evidence of a statistically significant increase in spreads is weak. While estimated coefficients on the dummy variable (D_t^L) are positive for the SPI and Bank Accepted Bills they are not significant at conventional levels. For the Three Year Bond and Ten Year Bond contracts the event dummy coefficients are positive at the 0.05 and 0.10 levels of statistical significance respectfully. Overall, these results provide little evidence of a statistically significant widening of bid-ask spreads following the increase in pre-trade transparency. The results suggest that limit order traders withdraw depth from the best quotes, but not to the extent that spreads often widen, consistent with H_2.

4.2 Test of Hypothesis 3

Table 4 provides results of tests of H_3. Consistent with H_3, the number and proportion of market orders (i.e. transactions) whose volume exceeds limit order volume at the best quotes increases following the change in transparency. The number of such

market orders, while small, increase from 753 to 2320 in the SPI, 43 to 136 in Bank Accepted Bills, 142 to 1035 in Three Year Bonds and 243 to 985 in Ten Year Bonds. In addition, the number of market orders that clear the best quotes as a proportion of the total number of transactions also increases across the four contracts examined. Table 3 documents that the increase in the proportion of market orders *clearing the best quotes* across all four contracts is significant at the 0.01 level based on a chi-square test.

These results are consistent with Hypothesis 3, and provide evidence of a change in trading behaviour surrounding the increase in pre-trade transparency on the SFE. Market order traders in the transparent environment no longer avoid executing orders which exceed depth available at the best quotes. In a transparent environment, depth information in the limit order book provides execution certainty for large orders and hence traders no longer suffer execution risk. Consistent with this argument, traders are executing a larger number of orders that exceed depth at the best quotes following the increase in pre-trade transparency.

It is possible that the increase in the number of market orders exceeding depth at the best quotes is merely a result of the decline in depth at the best quotes following the increase in pre-trade transparency. We examine trade packages to provide evidence of an increase in the size of large trades despite the decline in depth at the best quotes. Panel B of Table 3 documents a statistically significant increase in the average number of contracts per trade package at the 0.01 level, across the four contracts examined. Median trade package size also shows a statistically significant increase at the 0.01 level. These results provide evidence which suggests that the increase in the

number of market orders which clear depth at the best quotes is not merely a function of the decline in depth. The increase in the number of market orders clearing depth at the best quotes can therefore be more reasonably attributed to the increase in pre-trade transparency.

4.2 Robustness Tests

This section provides additional tests to examine the robustness of the evidence presented above which documents a decline in liquidity by way of a reduction in depth, and little change in bid-ask spreads following increased limit order book disclosure. The first robustness test divides the pre-event and post-event sample periods into subsamples in order to determine if the change in depth and bid-ask spreads presented in Table 3 is permanent through time. The pre and post-event sample periods are divided into two subsamples of an approximately equal number of trading days and assigned time period dummy variables. Subsample 1 in the pre-event period extends from October 2, 2000 to November 14, 2000 for the SPI and from September 15, 2000 to October 31, 2000 for the interest rate futures contracts.[16] Subsample 1 is not assigned a dummy variable. Subsample 2 in the pre-event period extends from November 14, 2000 to December 29, 2000 for the SPI and from November 1, 2000 to December 16, 2000 for the interest rate futures contracts.[17] The dummy variable *Pre-D* is assigned a value of 1 if the observation is drawn from subsample 2 in the pre-event period, or 0 otherwise. In the post-event sample period, subsample 1 extends from April 2, 2001 to May 16, 2001 for the SPI and from March 15, 2001 to May 1, 2001 for the interest rate futures contracts. The dummy variable *Post-*D_1 is assigned a value of 1 if the observation is drawn from subsample 1 in the post-event period, or 0 otherwise. Finally, Subsample 2 in the post-event period

extends from May 17, 2001 until June 29, 2001 for the SPI and from May 2, 2001 until June 15, 2001 for the interest rate futures contracts and is denoted by dummy variable *Post-*D_2.

Table 4 reports the results of regression analysis on depth and spreads with the inclusion of the time period dummy variables defined above. Panel A of Table 4 documents a reduction in $DEPTH_t$ for all contracts which is persistent across the post-event period subsamples. The coefficients on dummy variables *Post-*D_1 and *Post-*D_2 are negative and significant at the 0.01 level for all contracts. The robustness of our results is further emphasized by the significant decline in depth remaining despite the rise in depth prior to the opening of the limit order book, captured by *Pre-*D_2. The inclusion of time period dummy variables increases the explanatory power of the regression models to between 24% and 63% and they remain significant at the 0.01 level according to the *F*-statistics. In summary, these results provide further evidence consistent with H_1 suggesting that public display of the limit order book beyond the best quotes is associated with a permanent decrease in depth.

Results for the regression on bid-ask spreads are presented in Panel B of Table 4. Consistent with H_2 coefficients on the post event dummy variables are positive across the four contracts examined. However, the inclusion of the time period dummy variables weakens the statistical significance of the increase in bid-ask spreads documented in Table 3. The results fail to show a significant increase in bid-ask spreads for the Three Year Bond and Ten Year Bond contracts across both post event periods. The coefficient on the dummy variable *Post-*D_2 is significant at the 0.05 level for the Three Year Bonds and *Post-*D_1 is significant at the 0.01 level for the Ten Year

Bonds. No significant change in bid-ask spreads is reported for each of the post-event sample periods for the SPI and Bank Accepted Bill futures contracts. These results provide further evidence of little significant change in bid-ask spreads following an increase in the transparency of the limit order book.

As a second test of robustness regressions on depth and bid-ask spreads are estimated using an extended sample period of six months either side of the event dates. This sampling procedure includes futures data from five near term futures contract series surrounding the increase in pre-trade transparency and provides evidence as to whether the results presented in Table 3 are persistent over time. The pre-event sample period extends from July 21, 2000 to January 21, 2001 for the SPI and from July 28, 2000 to January 28, 2001 for the interest rate futures contracts. The post-event period extends from January 22, 2001 to July 22, 2001 for the SPI and January 29, 2001 to 29 July 2001 for the interest rate contracts.

The results for the depth and bid-ask spread regression models are presented in Panel C and Panel D of Table 4 respectfully. The overall explanatory power of the regression models and *t*-tests are marginally reduced over the larger sample period. One possible explanation is the failure to exclude a gestation period or control for time to expiration effects as in the main results. However, coefficients on the dummy variable (D_t^L) remain negative and significant across the four contracts examined at the 0.05 level. The decline in depth following the opening of the limit order book is therefore robust to the extended sample period. Panel D of Table 4, documents positive coefficients on the dummy variable D_t^L across the four contracts examined. The event dummy coefficient is significant only at the 0.10 level for the Bank

Accepted Bills and Ten Year Bond contracts. Thus, consistent with earlier results there is little evidence of a significant change in bid-ask spreads following the increase in pre-trade transparency. In summary, the finding of little change in average bid-ask spreads, following an opening of the limit order book, is robust to a twelve month widow surrounding the event date.

5. Conclusion

This paper examines the effect of limit order book disclosure on trading behaviour by examining an exogenous increase in pre-trade transparency on the SFE. We begin by developing a theoretical rationale which argues market order traders pay a liquidity premium for execution certainty, and consequently predict that depth will fall in a transparent market while spreads will be greater than or equal to spreads in a non-transparent market. Consistent with predictions, the increase in limit order book disclosure coincides with a statistically significant reduction in depth at the best quotes. The reduction in depth persists even after controlling for known determinants of depth. Furthermore, there is little evidence of a statistically significant change in bid-ask spreads. Finally, the frequency of market orders exceeding depth at the best quotes increases significantly. We conclude that in a transparent market, limit order traders charge a premium for execution certainty by withdrawing depth from the best quotes, but not by reducing bid-ask spreads. Market order traders are also more willing to submit orders which clear the best quotes and execute with limit orders behind the best quotes.

Table 1
Limit Order Book Liquidity

Descriptive statistics are provided for measures of market liquidity surrounding the increase in pre-trade transparency on the Sydney Futures Exchange. The transparency of the limit order book was increased from the best bid-ask prices to the three best bid-ask prices for the Share Price Index Futures Contract on January 22, 2001 and for the interest rate contracts on January 29, 2001. The pre-event sample period extends from October 2, 2000 to December 29, 2000 for the Share Price Index futures contract and from September 15, 2000 to December 16, 2000 for interest rate futures contracts. The post-event sample period extends from April 2, 2001 to June 29, 2001 for the Share Price Index Futures contract and from March 15, 2001 to June 15, 2001, for the interest rate futures contracts. Depth and bid-ask spreads are sampled each 20 minutes during the trading day. Depth is defined as aggregate limit order volume at the best buy and best sell price. The bid-ask spread is the best ask price minus the best bid price in contract points. A time series of daily averages are calculated. Both *t*-tests and Wilcoxon *z*-tests are used to determine whether the change in variables across the pre- and post-event periods is significant.

	Share Price Index			Bank Accepted Bills			Three Year Bonds			Ten Year Bonds		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Panel A: Depth												
Mean	37.99	28.65	-9.34	1427.61	867.13	-560.49	1914.00	1191.10	-722.90	176.48	116.36	-60.12
Median	32.45	29.23	-3.22	1264.61	801.82	-462.79	1796.98	1156.75	-640.22	159.68	114.53	-45.16
Std Dev	17.05	7.18		564.15	268.13		797.46	276.48		79.78	23.39	
n	63	60		65	61		66	62		66	62	
t-stat			-3.92*			-7.19*			-6.76*			-5.71*
z-stat			-3.37*			-6.43*			-6.45*			-6.37*
Panel A: Bid-Ask Spreads (Contract Points)												
Mean	1.048950	1.062018	0.013068	0.010056	0.010184	0.000128	0.010060	0.010175	0.000115	0.005114	0.005207	0.000093
Median	1.050000	1.050000	0.000000	0.010000	0.010000	0.000000	0.010000	0.010100	0.000100	0.005000	0.005104	0.000104
Std Dev	0.039784	0.068827		0.000164	0.000498		0.000186	0.000222		0.000190	0.000319	
n	63	60		65	61		66	62		66	62	
t-stat			1.30			1.96***			3.18*			2.02**
z-stat			0.60			0.07			7.87*			1.73**

* Significant at the 0.01 level
** Significant at the 0.05 level
*** Significant at the 0.10 level

Table 2
Determinants of Limit Order Book Liquidity

Descriptive statistics are provided for market variables, depth and spreads surrounding the increase in pre-trade transparency on the Sydney Futures Exchange. The transparency of the limit order book was increased from the best bid-ask prices to the three best bid-ask prices for the Share Price Index Futures Contract on January 22, 2001 and for the interest rate contracts on January 29, 2001. The pre-event sample period extends from October 2, 2000 to December 29, 2000 for the Share Price Index futures contract and from September 15, 2000 to December 16, 2000 for interest rate futures contracts. The post-event sample period extends from April 2, 2001 to June 29, 2001 for the Share Price Index Futures contract and from March 15, 2001 to June 15, 2001, for the interest rate futures contracts. Volume is measured as the daily total number of contracts traded. Price volatility is measured as the logarithm of the high price divided by the low price in the trading day. Daily contract volume and price volatility time series are constructed. Both *t*-tests and Wilcoxon *z*-tests are used to determine whether the change in variables across the pre- and post-event periods is significant.

	Share Price Index			Bank Accepted Bills			Three Year Bonds			Ten Year Bonds		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Panel A: Volume												
Mean	8675	7664	-1011	8363	9436	1073	21959	29968	8009	7633	9072	1439
Median	8631	7630	-1001	7402	8320	918	19192	24791	5599	6512	8114	1602
Std Dev	2373	2419		4945	5315		12375	16822		4219	5452	
n	63	60		65	61		66	62		66	62	
t-stat			-2.34**			1.17			3.08*			1.68**
z-stat			-2.22**			1.33			2.68*			1.59**
Panel B: Volatility												
Mean	0.008129	0.008473	0.000344	0.000372	0.000595	0.000223	0.000545	0.000826	0.000281	0.000546	0.000709	0.000163
Median	0.007473	0.007373	-0.000100	0.000321	0.000524	0.000203	0.000478	0.000736	0.000259	0.000506	0.000639	0.000133
Std Dev	0.002516	0.003888		0.000208	0.000339		0.000266	0.000350		0.000226	0.000242	
n	63	60		65	61		66	62		66	62	
t-stat			0.59			4.48*			5.13*			3.94*
z-stat			-0.50			3.49*			4.62*			3.83*

* Significant at the 0.01 level
** Significant at the 0.05 level
*** Significant at the 0.10 level

Table 3
Regression Analysis

Regression results are provided for models of depth and bid-ask spreads surrounding the increase in pre-trade transparency on the Sydney Futures Exchange. The transparency of the limit order book was increased from the best bid-ask prices to the three best bid-ask prices for the Share Price Index Futures Contract on January 22, 2001 and for the interest rate contracts on January 29, 2001. The pre-event sample period extends from October 2, 2000 to December 29, 2000 for the Share Price Index futures contract and from September 15, 2000 to December 16, 2000 for the interest rate futures contracts. The post-event sample period extends from April 2, 2001 to June 29, 2001 for the Share Price Index Futures contract and from March 15, 2001 to June 15, 2001, for the interest rate futures contracts. The parameters of the following depth regression model are estimated:

$$DEPTH_t = \alpha_0 + \beta_1 D_t^L + \beta_2 VOLUME_t + \beta_3 VOLATILITY_t$$

The parameters of the following bid-ask spread regression model are estimated:

$$BAS_t = \alpha_0 + \beta_1 D_t^L + \beta_2 VOLUME_t + \beta_3 VOLATILITY_t$$

Where $DEPTH_t$ is the logarithm of average limit order volume at the best buy and best sell quotes for day *t*. BAS_t is the logarithm of the average bid-ask spread for day *t*. Depth and bid-ask spreads are sample each 20 minutes during the trading day. D_t^L is a dummy variable assigned a value of 1 if the observation is drawn from the post-event period, or 0 otherwise. $VOLUME_t$ is the logarithm of total daily contract volume. $VOLATILITY_t$ is the logarithm of the high price divided by the low price for the day. All t-statistics are adjusted for heteroskedasticity and autocorrelation using the procedure developed by Newey and West (1987).

	Share Price Index		Bank Accepted Bills		Three Year Bonds		Ten Year Bonds	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Panel A: Depth								
Constant	1.4685	2.65*	6.0327	21.66*	5.9281	22.92*	3.3543	9.69*
D	-0.1899	-4.20*	-0.4427	-6.03*	-0.4161	-7.12*	-0.3408	-8.12*
Volume	0.2586	3.99*	0.1535	6.66*	0.1714	6.28*	0.2220	5.86*
Volatility	-29.1460	-3.16*	-466.2962	-3.26*	-236.2039	-4.09*	-371.3840	-4.63*
Adj R^2		0.2482		0.4492		0.3610		0.3775
F-stat		14.42*		34.98*		24.91*		33.39
n		123		126		128		128
Panel B: Bid-ask spreads (contract points)								
Constant	0.372628	8.72*	-4.357126	-110.01*	-4.509972	-187.86*	-4.952354	-44.02*
D	0.003170	0.95	0.002439	1.20	0.004845	2.61**	0.011784	1.91***
Volume	-0.038691	-8.06*	-0.030231	-6.59*	-0.010919	-4.46*	-0.040792	-3.00*
Volatility	2.915051	4.04*	64.763851	6.16*	31.666177	16.61*	63.824053	4.07*
Adj R^2		0.1030		0.3528		0.4596		0.1854
F-stat		5.67*		23.72*		37.01*		10.63*
n		123		126		128		128

* Significant at the 0.01 level
** Significant at the 0.05 level
*** Significant at the 0.10 level

Table 4
Market Orders Clearing Depth at the Best Quotes

This table presents descriptive statistics for market orders clearing depth at the best quotes and institutional trade packages. Trading in the near term contract for the four most liquid series trading on the Sydney Futures Exchange is examined surrounding the increase in pre-trade transparency on the exchange. The transparency of the limit order book was increased from the best bid-ask prices to the three best bid-ask prices for the Share Price Index futures contract on January 22, 2001 and for the interest rate contracts on January 29, 2001. The pre-event sample period extends from October 2, 2000 to December 29, 2000 for the Share Price Index futures contract and from September 15, 2000 to December 16, 2000 for the interest rate futures contracts. The post-event sample period extends from April 2, 2001 to June 29, 2001 for the Share Price Index Futures Contract and from March 15, 2001 to June 15, 2001, for the interest rate futures contracts. Panel A presents the number and proportion of market orders that exceed limit order volume at the best quotes. Tests of significance of the difference in proportions between the pre and post period sub-samples are made using a chi-square test. Panel B presents descriptive statistics of the size of institutional trade packages. A buy (sell) trade package is defined as a sequence of purchases (sales) by the same trader, consecutively without a 1-day trading break. The mean, median and standard deviation of the volume of contracts per institutional trade package are reported. Both *t*-tests and Wilcoxson *z*-tests are used to determine whether the change in variables across the pre- and post-event periods is significant.

	Share Price Index			Bank Accepted Bills			Three Year Bonds			Ten Year Bonds		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
Panel A: Market Orders Clearing Depth at the Best Quotes												
n	753	2320	1567	43	136	93	142	1035	893	243	985	742
n as a Proportion of Total No. Transactions (%)	0.5384	1.8320	1.2936	0.3220	0.7232	0.4012	0.3214	1.5493	1.2279	0.5531	1.6225	1.0694
Total No. Transactions	139869	126641		13354	18805		44175	66803		43937	60710	
Chi-square stat.			975.80 *			22.71 *			382.07 *			251.36 *
Panel B: Trade Packages												
Mean	94.40	105.97	11.57	212.52	230.65	18.13	275.12	356.12	80.99	95.02	115.26	20.24
Median	28	26	-2	100	100	0	114	150	36	31	44	13
Std Dev	213.76	296.82		327.12	345.77		484.81	621.99		228.80	301.88	
n	15144	13710		6204	7334		12498	13195		12443	12071	
t-stat.			3.83 *			19.87 *			11.60 *			17.34 *
z-stat.			2.72 *			25.74 *			12.01 *			59.55 *

*	Significant at the 0.01 level
**	Significant at the 0.05 level
***	Significant at the 0.10 level

Table 5
Robustness Tests

Two tests of robustness of the regression results provided for depth and spreads are performed. The first robustness test divides the pre and post-event sample periods into two sub-samples of approximately 30 trading days each and assigns dummy variables. Subsample 1 in the pre-event period extends from October 2, 2000 to November 14, 2000 for the Share Price Index futures contracts and from September 15, 2000 to October 31, 2000 for the interest rate futures contracts and is not assigned a dummy variable. Subsample 2 extends from November 14, 2000 to December 29, 2000 for the SPI and from November 1, 2000 to December 16, 2000 for the interest rate futures contracts. The dummy variable *Pre-D* is assigned a value of 1 if the observation is drawn from this period, or 0 otherwise. Subsample 1 of the post-event period extends from April 2, 2001 to May 16, 2001 for the Share Price Index Futures contracts and from March 15, 2001 to May 1, 2001 for the interest rate futures contracts and is denoted by dummy variable *Post-*D_1. Subsample 2 in the post event period extends from May 17, 2001 until June 29, 2001 for the Share Price Index futures contracts and from May 2, 2001 until June 15, 2001 for the interest rate futures contracts and is denoted by dummy variable *Post-*D_2.

For the second test of robustness, the sample size is increased to twelve months surrounding the change in pre-trade transparency on the Sydney Futures Exchange. The pre-event sample period extends from July 21, 2000 to January 21, 2001 for the Share Price Index futures contracts and from July 28, 2000 to January 28, 2001 for the interest rate futures contracts. The post-event period extends from January 22, 2001 to July 22, 2001 for the Share Price Index futures contract and January 29, 2001 to July 29, 2001 for the interest rate futures contracts. The parameters of the following depth regression model are estimated:

$$DEPTH_t = \alpha_0 + \beta_1 VOLUME_t + \beta_2 VOLATILITY_t + \beta_k D_k$$

The parameters of the following bid-ask spread regression model are estimated:

$$BAS_t = \alpha_0 + \beta_1 VOLUME_t + \beta_2 VOLATILITY_t + \beta_k D_k$$

All t-statistics are adjusted for heteroskedasticity and autocorrelation using the procedure developed by Newey and West (1987).

	Share Price Index		Bank Accepted Bills		Three Year Bonds		Ten Year Bonds	
	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Panel A: Depth – Time Period Dummy Variables								
Pre-D	0.0817	1.82***	0.5141	10.77*	0.2821	5.71*	0.1862	5.11*
Post-D_1	-0.1577	-4.30*	-0.1669	-4.88*	-0.3039	-6.62*	-0.2945	-10.19*
Post-D_2	-0.1343	-3.57*	-0.2621	-7.83*	-0.2599	-5.56*	-0.2200	-9.17*
Adj R^2		0.2435		0.6297		0.4257		0.4118
F-stat		8.85*		43.52*		19.83*		18.79*
n		123		126		128		128
Panel B: Bid-ask spreads – Time Period Dummy variables								
Pre-D	-0.004196	-1.01	-0.001287		0.004241	1.05	0.001454	0.31
Post-D_1	0.000587	0.09	-0.001881		0.005235	1.50	0.031061	7.16*
Post-D_2	0.001241	0.21	0.005112		0.008318	2.49**	-0.003080	-1.11
Adj R^2		0.0886		0.3477		0.4594		0.2343
F-stat		3.37*		14.32*		22.59*		8.77*
n		123		126		128		128
Panel C: Depth – Increased Sample Period								
D	-0.0641	-2.09**	-0.2020	-2.65*	-0.1946	-2.13**	-0.1700	-3.11*
Adj R^2		0.2169		0.2736		0.1714		0.2187
F-stat.		17.79*		23.91*		13.37*		17.82*
n		247		247		245		245
Panel D: Bid-ask spreads – Increased Sample Period								
D	0.000880	0.13	0.008829	1.84***	0.000002	0.01	0.006316	1.892508***
Adj R^2		0.1185		0.2156		0.2090		0.1330
F-stat.		9.02*		17.65*		16.87*		10.23*
n		247		247		245		245

* Significant at the 0.01 level
** Significant at the 0.05 level
*** Significant at the 0.10 level

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[1] Both the ASX and LSE allow hidden orders which reduce order book transparency. These hidden orders take the form of an order where part of the order volume is disclosed and the remainder is hidden. The entire order volume can also be hidden on the ASX.

[2] Supermontage was introduced on Nasdaq on October 14, 2002. The system displays the depth at the five best bid and ask prices. The complete schedule of limit orders is available for an additional subscription fee.

[3] Both regulatory bodies also argue that pre-trade transparency promotes fairness and efficiency in securities markets.

[4] ECN's include Instinet, Tradebook and Terra Nova. Some ECN's allow participants to view real time depth information from a limit order book managed by the ECN, for securities traded on organised secondary equities markets. However, other ECN's provide trader anonymity which represents a decrease in pre-trade transparency. Orders matched on an ECN are routed directly to the exchange avoiding execution by a broker.

[5] Porter and Weaver (1998) document the use of delayed trade reporting on Nasdaq. The authors do not explicitly examine the impact of delayed reporting on market quality, however evidence consistent with the use of late trade reporting to delay the release of strategic information is found.

[6] Bloomfield and O'Hara (1999) find that trade disclosure leads to greater informational efficiency, higher bid-ask spreads and a wealth transfer from informed and uninformed traders to market makers. In contrast, when quotes are disclosed Flood et al. (1999) find that opening spreads are smaller, volume is higher and price efficiency declines.

[7] Anand and Weaver (2003) observe that differences in the microstructure of the two experimental markets and as well as the type of transparency studied are likely to drive these differences.

[8] SYCOM was launched on 30 November 1989 as an overnight trading system. SYCOM enabled overseas investors to trade the Australian futures market during their day trading hours and allowed Australian investors to manage risk overnight. Upon its launch, SYCOM was the first after hours electronic trading system in the world.

[9] Prior to October 4, 1999 for interest rate products and November 15, 1999 for the Share Price Index futures contracts, day trading occurred in an floor traded market.

[10] The four major contracts examined in this study do not have designated dealers. Smaller less liquid series are assigned designated market makers.

[11] One possible strategy to reduce risk is for the traders to make an initial order just sufficient to clear away all the available volume at p_1 thereby revealing order volume at the next best price p_2. This trading strategy has its own risk in that the market will infer from an order of exactly this size that the trader is interested to some extent in proceeding with further trades in the same direction. The market may therefore move immediately against the trader, before any further trade is executed. Specifically, much or all of the volume available at p_2 may shift to p_3, meaning that the trader can only complete a larger order size at a worse average price than if he had made a single market order of this size in the first instance. Another possible strategy for reducing risk may include making an initial order just less than the available depth at p_1 in order to reduce the waiting time for order volume at p_1 to be cleared by other traders. These are two possible strategies to reduce risk, others are possible.

[12] Traders may employ other more elaborate or covert search strategies than merely clearing all the volume at p_1, but whatever strategy they apply they cannot achieve a certain average price per unit.

[13] Unfortunately data beyond depth at the best price steps prior to the change in limit order book disclosure is unavailable.

[14] Spurious results may be generated by the proportional bid-ask spreads in time series futures data. If a contracts bid-ask spread remains constant over time and the contracts price is trending, the proportional bid-ask spread will change.

[15] Given the higher liquidity of futures markets, a one day trading gap criterion is used rather than the five-day gap employed by Chan and Lakonishok (1995).

[16] The pre-event period consists of 63 trading days in the SPI futures contract. This odd number prohibits and equal division of trading days. Sub-sample 1 is assigned the first 32 trading days and sub-sample 2 consists of the remaining 31 trading days.

[17] There are two days of missing data for the Bank Accepted Bills futures contracts, one day in each of the pre-event subsamples.