Price formation and liquidity surrounding large trades in interest rate and equity index futures

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Abstract

This paper examines the effects of the direction of trade initiation and trade size on the resiliency of financial futures markets by analysing quote prices, bid-ask spreads and depths. The price and liquidity reactions reveal the unexpected information content of large trades, together with the motivation for exchanging a futures contract. In the market adjustment process, the size of quotes posted by liquidity providers are shown to play a more important role in futures markets than in previous research for equity markets. The liquidity cost of a large futures trade is mainly a pecuniary externality borne by other traders by impairing their continued ability to trade.

JEL classification: G13, G14

Keywords: Financial futures, Block trades, Price impact, Limit order book, Market resiliency

1. Introduction

The market impact of large futures trades and the speed of adjustment in the limit order book surrounding large-trade execution are assessed. In the microstructure literature in this area, futures markets have received considerably less attention than equity markets, despite the vital role they play in risk transfer and price discovery in global financial markets (Grossman and Miller, 1988). Previous work based on futures markets has concentrated on stock index futures. For example, Berkman, Brailsford and Frino (2005) examine the impact of different trade sizes using a small sample of two expiration cycles in the one year for the FTSE 100 stock index futures contract. They find only a small permanent price impact associated with trades in index futures, implying that trades in stock index futures are primarily liquidity motivated and carry little information. Their results are surprising given the inherent leverage and lower transaction costs of futures are likely to attract informed traders (Fleming, Ostdiek and Whaley, 1996). Even more surprising, they find no statistically significant relationship between permanent price effects and trade size. Further evidence is provided regarding the information signal conveyed by large trades using an extensive sample of twenty-eight expiration cycles spanning seven years for a suite of interest rate and equity index futures contracts that differ with respect to their risk profiles and baseline liquidity levels.

The analysis tests whether liquidity effects are significantly associated with information content as measured by trade size. Information asymmetry in futures markets, where investors trade to resolve differential private views on market-wide information, is likely to be fundamentally different in nature to information asymmetry in equity markets, where investors trade to exploit stock-specific information (Chan, 1992; Frino, Walter and West, 2000). In futures markets, information advantages are derived from superior information processing skills rather than from leakages of private information. Therefore, the liquidity supply response to large trades is analysed to determine whether liquidity providers in futures markets make the same strategic choices to those in equity markets. Specialists and other liquidity providers in equity markets have been shown to actively manage adverse selection risk by adjusting both bid-ask spreads and depth (Koski and Michaely, 2000). Furthermore, the systematic component of adverse selection that remains for contracts such as stock index futures written over a basket of securities, where the individual equity-specific component of adverse selection tends to be diversified away, is revealed (Subrahmanyam, 1991; Gorton and Pennacchi, 1993).

Research on how order-driven financial markets provide liquidity when large trades arrive is often confined to bid-ask spreads (for example Hasbrouck, 1991), with inadequate attention given to the inevitable disruptions to the supply of liquidity that sustains the continued ability to trade. The replenishment process for market depth, in particular, reflects how quickly the adverse selection problem dissipates after large block trades at the same time that there is a surge in demand to trade on the information contained in the block itself. An electronic limit order book operated without the presence of designated market-makers for the Australian futures market provides an ideal setting to explore these issues and widen the assessment of the liquidity response to include quoted depth. The absence of designated market-makers removes a market entry barrier that could otherwise sustain agency market power and influence patterns in liquidity provision and trading activity around large trades (Tse, 1999).[1] The electronic limit order book facilitates a study based on data that is captured online in real time and where all bids and offers are revealed to other traders through a continuous auction system of trading. Comparable data for other futures markets such as those operating in the United States are not available.

1.1 Price effects and speed of adjustment

This paper provides insights into the roles that the direction of trade initiation and trade size play in forming prices in futures markets. Easley and O'Hara (1987) show that trade size affects security prices because it is correlated with private information about the value of the security. Previous research provides empirical evidence of the price effects and speed of adjustment to large trades in equity markets.[2] Temporary price effects of large trades observed in equity markets have been ascribed to liquidity costs (including adverse selection, inventory control and search components), whereas permanent price effects are often ascribed to either inelastic demand conditions or the arrival of new information. Holthausen, Leftwich and Mayers (1990) in the United States and Aitken and Frino (1996) in Australia find that permanent price effects dominate temporary price effects for both block purchases and block sales in equity markets and these results hold across sub-samples of block size and alternative

[1] Many futures markets rely on the presence of locals, who trade as principals on their own accounts and act as 'voluntary market makers' in the sense that they provide liquidity to incoming market orders. Unlike the specialists at the New York Stock Exchange (NYSE) or the dealers at the National Association of Securities Dealers Automated Quotations (NASDAQ), locals have no obligation to recurrently bid or offer.

[2] Kraus and Stoll (1972), Holthausen, Leftwich and Mayers (1987; 1990), Hasbrouck (1988; 1991), Barclay and Warner (1993), Chan and Lakonishok (1993) and Koski and Michaely (2000) in the United States, Gemmill (1996) in the United Kingdom and Ball and Finn (1989), Aitken and Frino (1996) and Anderson, Cooper and Prevost (2006) in Australia among others provide empirical evidence from equity markets.

measures of price impact.[3] This paper examines the impact of trades of various sizes to provide equivalent evidence for financial futures markets.

The inherent leverage and lower transaction costs of futures are likely to attract informed traders. Fleming, Ostdiek and Whaley (1996) show that trading S&P 500 futures, for example, costs about 3 percent of the cost of trading an equivalent stock portfolio. As a result, they find that S&P 500 futures prices appear to lead the S&P 500 stock index, even after controlling for the effects of infrequent trading on the index. For market-wide information, price discovery occurs in the index futures market where trading costs are considerably less than the cost of trading the basket stocks in the index.[4] The structure of trading costs suggests that large futures trades should have permanent price effects because informed traders prefer to exploit their information advantages in the futures market rather than in the cash market. Informed buyers believe the futures contract is underpriced and informed sellers believe the futures contract is overpriced. The trade size could represent the quality of the information contained in their trades (Chan and Lakonishok, 1993).

Several prior studies based on equity markets establish an asymmetry between purchases and sales in the price reaction following large transactions (Kraus and Stoll, 1972; Holthausen, Leftwich and Mayers, 1987; 1990; Chan and Lakonishok, 1993; Aitken and Frino, 1996; and Gemmill, 1996). These studies show that prices remain high after block purchases whereas they tend to revert back towards pre-trade levels after block sales. The different price reactions between purchases and sales could reflect the reluctance of brokers to accommodate clients' purchases by undertaking short positions. Alternatively, purchases might convey a stronger signal of favourable information, whereas there are numerous liquidity-motivated reasons to dispose of stock (Chan and Lakonishok, 1993). Futures markets differ from equity markets at least to the extent that there are no additional costs for traders taking short positions compared to long positions. Without the constraints on short sales experienced in equity markets, there are potentially as many informed sellers as informed buyers. In these conditions, there should be no asymmetry in the price reaction between purchases and sales.

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[3] Holthausen, Leftwich and Mayers (1990) define blocks as the largest fifty trades by number of shares traded for each stock by tick type. Similarly, Aitken and Frino (1996) define blocks as the largest one percent of on-market trades for each stock over their sample period.

[4] Berkman, Brailsford and Frino (2005) confirm that the execution costs paid by the initiators of large trades in the FTSE 100 stock index futures contract are substantially lower than for large on-market trades in index-constituent equities on the London Stock Exchange (LSE). Similarly, Frino and Oetomo (2005) demonstrate that the slippage costs incurred in executing packages of trades that are likely to belong to the same original orders are significantly lower in futures markets than in equity markets.

There is little empirical evidence of the price effects of large trades in futures markets.[5] Using the FTSE 100 stock index futures contract traded on the London International Financial Futures and Options Exchange (LIFFE), Berkman, Brailsford and Frino (2005) find there is only a small permanent price impact associated with trades in index futures. Their results reveal that much of the initial price reaction is reversed, especially for large trades. Furthermore, they find no evidence of asymmetry in the price reaction following large trades in stock index futures, suggesting that the asymmetry documented in previous studies is specific to equity markets. This paper examines whether the price recovery documented for London equity index futures is evident in the price changes surrounding large trades for a suite of Australian interest rate and equity index futures. In doing so, previous research documenting that large trades contribute to the information dissemination process is extended to a broader range of financial futures contracts.

This paper analyses how quickly prices adjust to a new equilibrium after a large block trade to determine whether incentives exist for liquidity providers to restrict the size of sequential price changes in futures markets. Dann, Mayers and Raab (1977) present early evidence of the speed of adjustment of stock prices to large block transactions on the NYSE. They find that although the adjustment is rapid, the prices do not appear to be unbiased estimates of closing prices until more than ten minutes after the occurrence of a block trade. They suggest the anomaly could be due to transactions observed in the immediate post-block period that are part of the compensation offered to NYSE members to absorb the block (the 'compensation' hypothesis) or to obligations on specialists to restrict the size of sequential price changes (the 'orderly market' hypothesis). Faster adjustment times are expected in futures markets, where there are no affirmative obligations of market-makers to maintain smooth and orderly price changes.

Holthausen, Leftwich and Mayers (1990) find that prices rebound quickly after a block trade on the NYSE. For buyer-initiated trades, the price reversal takes one trade at most. For seller-initiated trades, most of the recovery occurs within one trade of the block and the recovery is complete within three trades. Holthausen, Leftwich and Mayers' results indicate that the speed of response depends on block size: the larger the block, the slower the adjustment.

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[5] Using intraday data on German index futures, Kempf and Korn (1999) analyse the price impact of net order flow measured as the difference between buyer and seller-initiated trading volume in each one minute interval. They find the information content of order flow increases with its size. However, their research is confined to stock index futures and they do not consider the price effects of large individual trades.

They argue this will be the case if larger blocks induce traders to offer price concessions on subsequent sales to avoid inventory holding costs and if traders reduce their inventory immediately after the block.[6] The price adjustment to large futures trades is observed to determine whether there is any support for the compensation hypothesis, the orderly market hypothesis or an inventory management explanation in futures markets.

1.2 Liquidity effects and speed of adjustment

In view of the distinctive price effects of large futures trades, the market response to large-trade activity is further probed by examining changes in liquidity surrounding large-trade execution, as well as the time taken for liquidity to return to normal. Moulton (1998) describes a "decrease in liquidity after a large trade that returns quickly to pre-trade levels" as a sign of market resiliency (see also Bernstein, 1987). Evidence presented by Moulton indicates liquidity drops after large equity trades on the NYSE then returns to pre-large trade levels quickly, both in terms of quote update time (within roughly three quotations) and clock time (within roughly fifteen minutes).[7] He also finds that the return of liquidity to normal levels is significantly related to whether limit orders or specialist orders provide counterparty volume to the large trade and to security-specific attributes such as trading activity and bid-ask spread widths, rather than whether it is a purchase or a sale and the relative size of the trade. Given the alternative structure of electronic limit-order driven futures markets where any potential counterparties are required to post visible quotes, this study endeavours to establish equivalent benchmarks for market resiliency and test whether the speed of liquidity recovery is essentially a product of contract-specific attributes. The proxy suggested by Moulton, the time taken for both spreads and depths to return to pre-trade levels, is adopted as a measure of the resiliency of interest rate and equity index futures markets to the impact of large trades. Thus, a more comprehensive analysis of market resiliency is obtained.

The liquidity supply response to large futures trades is analysed to determine whether liquidity providers in futures markets make the same strategic choices to those in equity markets. Specialists and other liquidity providers in equity markets actively manage adverse

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[6] Inventory costs are small in futures markets. Manaster and Mann (1996) show that the median S&P 500 index futures trader reduces inventory by almost fifty percent in one trade, whereas Hasbrouck and Sofianos (1993) and Madhavan and Smidt (1993) find that it takes an equity specialist a matter of weeks to reduce an inventory imbalance to the same extent.

[7] To investigate the systematic changes in quoted liquidity around large trades on the NYSE, Moulton (1998) develops a quoted liquidity metric to indicate the number of shares that can be traded per unit cost (the inverse of the slope of the equity specialist's demand curve).

selection risk by adjusting both bid-ask spreads and depth. Kavajecz (1999) demonstrates that depths are used as a strategic choice variable by NYSE specialists, documenting changes in quoted depth consistent with specialists managing their inventory positions as well as having knowledge of the future price of the stock. Koski and Michaely (2000) document that spreads increase significantly and depths decrease significantly after large trades on the NYSE, though not after small trades. They also show that excess spreads above a pre-trade benchmark after large purchases are relatively greater during dividend announcement periods, when information asymmetry is higher, than during ex-dividend periods.

The findings of other studies are consistent with an increase in adverse selection risk after large trades. For NYSE-listed equities, Lee, Mucklow and Ready (1993) document that bid-ask spreads widen and depths drop after volume shocks; liquidity suppliers use increased volume to infer the presence of informed traders. Hasbrouck (1991) shows, by estimating vector autoregressive (VAR) models for trades and quote revisions, that large trades induce an increase in the spread and trades which occur in the face of a relatively wide spread have a greater price impact than those which occur when spreads are narrow. The results of these studies are consistent with the Easley and O'Hara (1992a) prediction that volume shocks are associated with higher information risk and lower market liquidity.

In futures markets, any increase in adverse selection risk after large trades is likely to originate from *systematic* factors. Subrahmanyam (1991) and Gorton and Pennacchi (1993) show that adverse selection costs can be expected to be lower in equity index futures markets than in the underlying equity markets because the individual equity-specific component of adverse selection tends to be diversified away in contracts written over a basket of securities.[8] Suppliers of liquidity are less exposed to the risk of private information pertaining to individual equities.[9] Subrahmanyam shows that the diversification of systematic information further reduces adverse selection in the index futures market relative to the underlying equity markets, even when there are traders who are informed about the systematic component of

[8] The absence of 'upstairs trading' in an off-market block trade facility for interest rate futures contributes to the low adverse selection component of execution costs in the downstairs market, because liquidity-motivated traders do not have the option to use the services of an upstairs broker to obtain lower trading costs (Bessembinder and Venkataraman, 2003).

[9] The low risk of private information in futures markets does not imply that futures trades are bereft of any information content. Futures markets are shown to be driven by public information in the form of macroeconomic news, as discussed in the next section. Hasbrouck (1991) points out that the requirement in analyses which relate trading and price movements that public information is not useful in predicting the trade innovation is most likely to be violated when there are market features which impair the quote revision process and thereby constrain the quote revisions from fully reflecting public information.

equity values, if the sensitivities to systematic risk differ in sign across the individual equities. The analysis of the liquidity impact of large trades presented in this paper reveals what systematic component of adverse selection risk remains for interest rate and equity index futures when these diversification benefits are realised.

With regard to the speed of recovery in the limit order book, Biais, Hillion and Spatt (1995) analyse the interrelated dynamics of the order flow and order book for equities traded on the Paris Bourse. They find investors place limit orders when bid-ask spreads are wide or the order book is thin, providing liquidity when it is valuable to the marketplace. Following market orders, the market response to restore the prior state of the book is rapid (taking less than ninety seconds), which Biais, Hillion and Spatt attribute to intense competition in supplying liquidity[10]. Limit order traders monitor the order book and wait for favourable order placement opportunities. This study seeks to ascertain how quickly limit order placement opportunities re-emerge as liquidity providers adjust their price expectations and safeguard against the adverse selection problem following large trades in futures markets.

This paper tests the predictions of information models that incorporate quoted depth. Recognising that the size of quotes posted by market makers have received scant research attention relative to the price of quotes, Mann and Ramanlal (1996) model the adverse selection component of the bid-ask spread and the corresponding component of the size of quotes in a competitive dealership market. They argue that the quote size is a more informative indicator of market liquidity, defined as the relative market power of liquidity traders versus informed traders, than the adverse selection component of the spread.[11] Dealers lower their quote sizes as a first response to a decrease in market liquidity, and only when the quote sizes are at a minimum do they resort to wider spreads. This paper tests two implications of the theoretical model developed by Mann and Ramanlal: (i) the extent to which liquidity providers maintain lower quote sizes as a first response to the disruption to market liquidity caused by a large trade; and (ii) the extent to which the quote sizes are slower to recover than the spreads.

[10] Similarly, Aitken, Frino and Sayers (1994) do not detect any significant disruption to spreads surrounding block trades in Australian equities.

[11] Mann and Ramanlal (1996) show that the rate at which the size quotes become increasingly asymmetric reflects the rate at which private information is impounded in prices. Block trades could improve the informational efficiency of futures markets, to the extent that they instantly make the size of quotes asymmetric.

With reference to the liquidity adjustment surrounding large trades, this paper examines how the trading costs incurred by limit order traders as suppliers of liquidity are passed through to the consumers of liquidity in futures markets. Market liquidity is modelled by Grossman and Miller (1988) as being determined by the demand and supply of immediacy to trade now rather than wait to trade later. Demsetz (1968: 35-6) describes the bid-ask spread as "the markup that is paid for predictable immediacy of exchange in organised markets". In the context of a competitive futures market, the demand for immediacy is elastic due to the availability of liquidity in substitute securities and the supply of immediacy is also elastic due to the low risk of trading with better informed investors. Two consequences of these demand and supply conditions for the market adjustment to large trades are expected: (i) to the extent that liquidity suppliers anticipate an intra-day increase in the demand for immediacy, unquoted latent depth will be converted to an increase in quoted depth and higher volumes traded per unit of time while spreads remain close to the minimum tick and; (ii) when a large trade creates a temporary disruption to the supply of immediacy, the disruption is expected to be realised primarily in the form of a reduction in quoted depth (lower size quotes) rather than through substantially wider spreads. In particular, the liquidity cost of a large trade will be a pecuniary externality borne by other traders by impairing their continued ability to trade in large quantities over the interim period.

1.3 Information content of futures trades

The information disseminated through futures trading has two features that distinguish it from other kinds of information affecting market prices. The first feature relates to the source of the information. Futures market price volatility and volume are shown to be driven by public information released in the form of macroeconomic news, for interest rate and foreign exchange futures (Ederington and Lee, 1993) and equity index futures (Tse, 1999).[12] In making an investment decision based on public information, investors gain an advantage from superior information processing skills rather than from having seen the numbers first.[13] The futures price adjustment is observed in this study to infer the unexpected informational content of large trades derived through macroeconomic analysis and the interpretation of market-wide events. In particular, the objective is to isolate the portion of information that is

[12] Similarly, Fleming and Remolona (1997) find that the largest price shocks and the greatest surges in trading activity in the United States Treasury securities market stem from the arrival of public information, especially when taking account of the surprise component of a given announcement.
[13] Strictly defined, public information is that which affects prices before anyone can trade on it (French and Roll, 1986: 9). This definition ignores any heterogeneity in information processing ability among market participants.

delivered to futures markets through large trades, to distinguish it from information that is delivered through other forms of information media.[14]

The second feature of the information contained in futures trades is that its timing is unpredictable relative to scheduled economic announcements. Despite the low inventory costs in futures markets, locals are less able to protect themselves against unwanted inventory derived from unexpectedly large trades than that derived from the unexpected components of macroeconomic data releases. Seeing that macroeconomic news may alter futures prices immediately and significantly, traders will quote a higher ask or lower bid at the release time, to avoid unwanted inventory (as shown by Tse, 1999 in the United Kingdom). In contrast to the regularity of macroeconomic data, there is no equivalent forewarning of large trades in a continuous auction system of trading. The information contained in large trades may reach the market at any time during the trading day, including the periods after the market opening and following the official release of macroeconomic data. The only cue to locals of an impending large trade is through systematic interdependency in the order flow.

The distinct source and uncertain timing of the information revealed in large futures trades necessitates that the efficiency of futures markets in responding to these trades be evaluated, relative to their efficiency in responding to macroeconomic announcements analysed in prior research. Ederington and Lee (1995) find that the major adjustment of United States interest rate and foreign exchange futures prices to a scheduled macroeconomic news release is complete within 40 seconds of the release and zero drift is observed after three minutes. Not all studies are unequivocal about the rapid reaction of futures prices to macroeconomic announcements. Becker, Finnerty and Kopecky (1996) find that the reaction of Eurodollar and Treasury bond futures prices to unexpected news about the merchandise trade balance appears to be delayed; while in the case of consumer price index and non-farm payroll news shocks, prices tend to under-react initially. They attribute this anomalous price behaviour to some unspecified bias in using Money Market Services (MMS) forecasts to derive the unexpected components of macroeconomic data releases or, alternatively, market inefficiency.

[14] Large trades can have permanent price effects and appear to contain original information, simply because they transmit information from the underlying cash market to the futures market.

The news effects of Australian scheduled macroeconomic announcements including the consumer price index inflation rate, the gross domestic product growth rate and the retail sales growth rate on Australian 10 year government bond futures traded on the Sydney Futures Exchange are investigated by Kim and Sheen (2001). Their results indicate that most of the price adjustment and volatility response are concluded within the first minute of trading after the 11.30 a.m. announcement. In comparison, this study determines whether the speed of adjustment in response to large trades is as rapid as previous evidence suggests it is in response to new information relevant for bond pricing contained in scheduled economic information releases.

Block trades may provoke subsequent trading activity in much the same way that has been shown for macroeconomic news. Enlightening in this respect, Fleming and Remolona's (1999) exposition on inter-dealer trading in the United States five-year Treasury note market around the release times of major macroeconomic announcements reflects the primary motivation for trading in markets dominated by public information. They discover a two-stage adjustment to such public information. In a brief first stage, the release induces a sharp and nearly instantaneous price change accompanied by dramatically wider bid-ask spreads and a reduction in trading volume. Market makers evidently widen or withdraw their quotes to manage the inventory risk of sharp price changes. In a prolonged second stage, trading volume surges and persists along with high price volatility and moderately wide bid-ask spreads. Fleming and Remolona attribute the extended second phase of the adjustment process to residual disagreement among investors about what the just-released information means for prices.[15]

For futures markets, this paper contends that the market response to large trades will resemble the two-phase response to news releases described by Fleming and Remolona (1999), because both the initial inventory risk and the motivation for frenetic follow-up trades are similarly based on a public information event (albeit an impromptu event). A large on-market trade instantly transmits information from the private domain into the public domain. The information signal in the trade is inclined to excite the market. Traders then seek to re-establish a consensus on the meaning of the large trade for prices, until they consider that it is

[15] Alternative explanations for the delayed rise and slow decline in trading volume after announcements include portfolio rebalancing after significant price changes and the unwinding of speculative positions established during the few minutes prior to announcements. Fleming and Remolona (1999) point out that these activities may be expected to lead to a surge in volume, but not persistently high volatility.

no longer profitable for them to contribute to the debate. The increased trading activity prompts a rapid recovery in the bid-ask spread, as liquidity suppliers respond to the increased demand for immediacy. This argument predicts that a block trade produces an increase in risk (reflected in higher volatility after the trade) that stimulates an increase in trading activity, as traders rush to express differences of opinion about the price implication of the block.

In relation to the price formation process, the market response may indicate the extent to which block trades have the capacity to change the average reservation price across traders and, separately, to provoke greater disagreement among traders when they revise their reservation prices for the futures contract. Traders exchange a futures contract because they interpret the same piece of information differently, reaching different conclusions about the probabilities of future events. With traders disagreeing on the interpretations of private signals, Hindy (1994) analyses the doubled-sided auction price formation mechanism in a purely speculative futures market in the absence of liquidity traders and a designated market maker. He shows that trading volume and changes in prices are related to two different properties of the information flow pattern; volume is related to the reversals or fluctuations over time of a typical trader's private signal around the average signal, while changes in prices are related to changes in the median of signals. Similarly, Tauchen and Pitts (1983) derive and estimate a model of the 90-day United States Treasury bills futures market, where the market clearing price is the average reservation price across traders and the trading volume is proportional to the average absolute deviation of the reservation price changes about their mean. In this sense, the average trade represents a swing in views.

The remainder of this article is organised as follows. Section 2 describes the institutional setting, sample and methodology. Results concerning price effects are in section 3. Section 4 presents results about liquidity. Section 5 concludes.

2. Market structure, sample and methodology

2.1 Institutional setting

This study examines market orders executed on the Sydney Futures Exchange (SFE). The SFE is the thirteenth largest futures exchange in the world by volume traded and the third largest in the Asia-Pacific region (Burghardt, 2007: 28). The exchange operates an electronic trading system, which facilitates a study based on data that are captured online in real time.

The main interest rate contracts, 90 Day Bank Accepted Bills Futures, 3 Year Commonwealth Treasury Bond Futures and 10 Year Commonwealth Treasury Bond Futures, are among the top fifteen most actively traded in the world in their respective asset classes. The equity index contract, SFE SPI 200™ Index Futures, is written over the investment benchmark for the Australian equity market.

SFE's electronic trading system, Sydney Computerised Market (SYCOM®), operates 24 hours a day. The system allows brokers to route client orders from computers located in their offices to the central market. The day session commences at 8:30 a.m. and finishes at 4:30 p.m. Sydney local time for the interest rate contracts and commences at 9:50 a.m. and finishes at 4:30 p.m. for SFE SPI 200™ futures. The contracts expire in March, June, September and December each year. The minimum ticks for the interest rate contracts are one basis point (0.01 annual percentage yield), one basis point and half a basis point representing approximately 24, 28 and 40 Australian dollars per contract (varying with the level of interest rates) for 90 day bank bill futures, 3 year Treasury bond futures and 10 year Treasury bond futures respectively. The minimum tick for SFE SPI 200™ futures is one index point representing a fixed amount of 25 Australian dollars per contract. Limit orders are queued for execution using price then time priority. SYCOM allows traders to see the order depth at the three best bid and ask prices. Transaction prices and volumes are recorded and reported immediately.

2.2 Data and sample

Reuters intraday trade and quote data for the four major contracts traded on the exchange were provided by the Securities Industry Research Centre of Asia-Pacific (SIRCA). These are 90 day bank bill futures, 3 year Treasury bond futures, 10 year Treasury bond futures and SFE SPI 200™ futures. The SFE became a fully electronic exchange from 15 November 1999 and SFE SPI 200™ futures were launched on 2 May 2000. Therefore, the sample years 2001 to 2007 are selected to allow an extensive sample of trades.[16] To obtain a structural break-free data set for 3 year Treasury bond futures, the sample excludes the period from 8 December 2006 when new minimum tick arrangements were introduced. The study focuses on normal trading during day sessions in the second nearest contract maturity for 90 day bank

[16] Over the seven year sample period, the spot price of 90 day bank bills decreased from 93.77 to 92.62 (expressed as one hundred minus the yield published by the Reserve Bank of Australia) and the S&P/ASX 200 spot index value increased from 3,261.1 to 6,176.9.

bill futures and the nearest contract maturity for the other three contracts, to ensure that the results pertain to the most liquid segment of the market.[17]

Before conducting any analysis, two exclusion criteria are applied to reduce the possibility of extraneous events confounding the analysis. Firstly, trades executed with less than 10 trading days remaining to the last trading day for the nearest-to-maturity contract are excluded to avoid any bias in measuring quote price and liquidity changes due to transactions associated with investors closing out their positions in the near contract.[18] Secondly, trades within the first 20 quote revisions or the last 20 quote revisions of the day are excluded to obtain continuous series that demonstrate adjustments to the order book surrounding trades. The main sample resulting from the application of these two criteria is described below.

	90 day bank bill futures	**3 year treasury bond futures**	**10 year treasury bond futures**	**SFE SPI 200™ futures**
Initial sample	272,059	644,105	903,938	4,596,696
Excluding trades with:				
Less than 10 subsequent trading days to expiration	-	103,531	139,033	687,741
Less than 20 preceding or 20 subsequent quotes within the day	12,942	18,399	23,228	28,590
Main sample	**259,117**	**522,175**	**741,677**	**3,880,365**
Excluding trades with:				
Less than 20 preceding or 20 subsequent trades within the day	59,080	33,897	37,812	32,240
Trade sub-sample	**200,037**	**488,278**	**703,865**	**3,848,125**

[17] The SFE introduced an off-market block trade facility for SFE SPI 200™ futures from 1 May 2001, with a minimum threshold of 500 lots reduced to 300 lots from 30 August 2002 and reduced again to 200 lots from 23 October 2006. Only a very small portion of SFE SPI 200™ futures trades are arranged through the off-market facility. In 2007, 98,794 lots were transacted off-market, representing 1.2 percent of the total volume. Trades arranged through the off-market facility are excluded from the sample, given that different order arrangement and publication rules apply to these trades.

[18] Frino and McKenzie (2002) document a sharp increase in the magnitude of calendar spread mispricing for SFE SPI 200™ futures immediately prior to maturity of the near contract, related to a sharp decline in open interest in the near contract and an increase in open interest in the deferred contract.

The main sample of trades was then ranked by size and divided into tertiles based on cumulative volume (such that there is roughly the same aggregate volume in each size category). Blocks represent the largest group and are defined in terms of the number of contracts: trades of at least 574 lots in 90 day bank bill futures, 500 lots in 3 year Treasury bond futures, 150 lots in 10 year Treasury bond futures or 15 lots in SFE SPI 200™ futures.[19] Table 1 provides descriptive statistics on the characteristics of the sample trades in the four contracts. There is an average of 146 trades per day in 90 day bank bill futures, 409 trades per day in 3 year Treasury bond futures, 498 trades per day in 10 year Treasury bond futures and 2,615 trades per day in SFE SPI 200™ futures across the seven years included in the main sample. While SFE SPI 200™ futures are more frequently traded than the three interest rate contracts, the interest rate contracts are traded in much larger parcels (in terms of the average notional value per trade) with the average parcel size decreasing in the duration of the underlying interest rate.

Table 1 also provides summary statistics for block purchases and sales. On average, there are 2 block purchases and sales per day in 90 day bank bill futures, 8 block purchases and sales per day in 3 year Treasury bond futures, 9 block purchases and sales per day in 10 year Treasury bond futures and 76 block purchases and sales per day in SFE SPI 200™ futures included in the main sample. The average value of a block purchase ranges from 2.7 million Australian dollars for SFE SPI 200™ futures to 1.2 billion Australian dollars for 90 day bank bill futures.

[19] Additional analysis is undertaken using alternate trade size categories and the results are broadly similar to those reported in this article.

Table 1
Descriptive statistics

Panel A: 90 day bank bill futures

	1-199 lots	200-573 lots	574 + lots	Total
Purchases				
Number	107,992	16,771	3,841	128,604
Volume	3,742,781	5,284,779	4,614,812	13,642,372
Avg. # contracts/trade	34.7	315.1	1,201.5	106.1
Avg. # counterparties/trade	1.3	2.9	6.3	1.6
Sales				
Number	110,635	16,149	3,729	130,513
Volume	3,746,668	5,089,597	4,321,251	13,157,516
Avg. # contracts/trade	33.9	315.2	1,158.8	100.8
Avg. # counterparties/trade	1.3	2.9	6.1	1.6

Panel B: 3 year treasury bond futures

	1-199 lots	200-499 lots	500 + lots	Total
Purchases				
Number	224,319	25,563	10,700	260,582
Volume	7,841,688	7,029,163	9,089,011	23,959,862
Avg. # contracts/trade	35.0	275.0	849.4	91.9
Avg. # counterparties/trade	1.5	3.9	7.6	2.0
Sales				
Number	225,753	25,420	10,420	261,593
Volume	7,667,556	6,910,032	8,726,670	23,304,258
Avg. # contracts/trade	34.0	271.8	837.5	89.1
Avg. # counterparties/trade	1.5	3.9	7.7	2.0

Panel C: 10 year treasury bond futures

	1-49 lots	50-149 lots	150 + lots	Total
Purchases				
Number	297,100	53,250	14,054	364,404
Volume	2,997,743	4,104,330	3,835,024	10,937,097
Avg. # contracts/trade	10.1	77.1	272.9	30.0
Avg. # counterparties/trade	1.4	3.0	6.1	1.8
Sales				
Number	311,516	52,540	13,217	377,273
Volume	3,083,581	4,038,100	3,527,202	10,648,883
Avg. # contracts/trade	9.9	76.9	266.9	28.2
Avg. # counterparties/trade	1.4	3.0	6.0	1.8

Panel D: SFE SPI 200™ futures

	1-4 lots	5-14 lots	15 + lots	Total
Purchases				
Number	1,335,975	466,250	113,516	1,915,741
Volume	2,247,483	3,499,231	2,912,530	8,659,244
Avg. # contracts/trade	1.7	7.5	25.7	4.5
Avg. # counterparties/trade	1.1	2.0	3.5	1.5
Sales				
Number	1,389,288	463,221	112,115	1,964,624
Volume	2,313,025	3,472,691	2,891,839	8,677,555
Avg. # contracts/trade	1.7	7.5	25.8	4.4
Avg. # counterparties/trade	1.1	2.0	3.6	1.5

Descriptive statistics regarding purchases and sales of 90 day bank bill futures (Panel A), 3 year treasury bond futures (Panel B), 10 year treasury bond futures (Panel C) and SFE SPI 200™ futures (Panel D).

In the tables and figures in this article, results are reported in quotation event time. To provide some indication of the relative clock time for these events, the time intervals between quote revisions surrounding purchases and sales of different sizes are documented in appendix 1.[20] Quotes are updated approximately every 38 seconds for 90 day bank bill futures, every 19 seconds for 3 year Treasury bond futures and 10 year Treasury bond futures and every 4 seconds for SFE SPI 200™ futures. When large block trades occur, the average time elapsed since the last posted quote is about 46 seconds for 90 day bank bill futures, 25 seconds for 3 year Treasury bond futures, 29 seconds for 10 year Treasury bond futures and 6 seconds for SFE SPI 200™ futures. Quotes are revised after large block trades within 7 seconds for 90 day bank bill futures, within 4 seconds for 3 year Treasury bond futures, within 5 seconds for 10 year Treasury bond futures and within 3 seconds for SFE SPI 200™ futures.

Easley and O'Hara (1987) demonstrate that the entire sequence of trades, not merely aggregate trade size, determines the market impact of block trades because liquidity providers use the trading sequence to infer the probability of an information event. The direction of initiation, size and frequency of the sequence of trades surrounding the block futures trades are reported in appendix 2. Purchases and sales arrive at the market in clusters with other trades in the same direction and large trades are accompanied by other larger than average trades. This suggests that the price and liquidity effects of futures block trades documented in this article culminate from the sequence of surrounding trades acting in combination with the block itself, rather than from individual block trades acting independently of the surrounding order flow.

To facilitate the analysis of the market impact and speed of adjustment surrounding trades of different sizes, data are also collected on all trades of 1 to 199 lots in 90 day bank bill futures or 3 year Treasury bond futures, 1 to 49 lots in 10 year Treasury bond futures or 1 to 4 lots in SFE SPI 200™ futures (defined as small trades) and 200 to 573 lots in 90 day bank bill futures, 200 to 499 lots in 3 year Treasury bond futures, 50 to 149 lots in 10 year Treasury bond futures or 5 to 14 lots in SFE SPI 200™ futures (defined as medium-size trades). Smaller trades occur much more frequently than larger trades. For example, there are more

[20] The description of the time intervals between quotes surrounding trades of different sizes is an attempt to redress, in some part, the statistical problem identified by Easley and O'Hara (1992b: 599): "A researcher watching transaction prices (and ignoring clock time and quantities) is allowing the market participants to select random observations of the underlying price process with sampling times correlated with the evolution of the process."

than 107,000 small (1 to 199 lot) purchases of 90 day bank bill futures, compared to 16,771 medium purchases of 200 to 573 lots and 3,841 large block purchases.

2.3 Classification and aggregation of buy and sell transactions

A quote-based rule is used to classify purchases and sales. Specifically, all trades that occur above or equal to the prevailing ask price are classified as purchases and all trades that occur below or equal to the bid price are classified as sales. Excluded from the initial sample are trades that occur in the opening single price auction (under a call market regime) and trades that occur inside the spread during normal trading.[21]

The electronic limit order book enables brokers to execute large transactions (via market orders) against standing limit orders placed by a number of different counterparties at a number of different sequential price levels. Such transactions are reported as separate individual trades with consecutive time stamps. At the same time, quote revisions that occur as the market order cuts into the limit order book are not reported if the series of individual trades results from the same market order. For the purposes of this study, a sequence of individual trade records is grouped into a single aggregate trade record which belongs to the same market order. Specifically, individual trade records are grouped into an aggregate trade record if they are executed (i) with the same bid and ask quotes prevailing immediately before the trade, (ii) in the same direction and (iii) within 5 seconds of each other. The size of the aggregate trade is the sum of the sizes of the individual constituent trades in number of contracts.

2.4 Excess return and excess spread calculations

Koski and Michaely (2000) demonstrate that transaction prices are a biased measure of the effect of information on prices because price effects are obscured by noise associated with bid-ask bounce. Therefore, this bias is avoided by analysing quoted prices, spreads and depth. This paper characterises the speed of adjustment in the market by the quote-to-quote price and liquidity changes that occur from ten quotes before to twenty quotes after each block.

[21] Less than 0.25 percent of the trades captured during normal trading in each of the four contracts could not be classified because they occur inside the spread and were excluded from the sample.

Following Holthausen, Leftwich and Mayers (1990) and Koski and Michaely (2000), a benchmark return series is constructed for each contract maturity from the returns for quotes -20 through -11 relative to all trades of a given size. Mean excess returns are computed across purchases or sales of given size *z* for each contract. The methodology in equation (1) is used to compute mean excess returns for small ($z = 1$), medium ($z = 2$) and large ($z = 3$) purchases and sales as follows:

$$\overline{RX}_t(z) = \frac{\sum_{i=1}^{28} \sum_{j=1}^{N_{i,pur}(z)} [R_{i,j,t}(z) - BEN_i(z)]}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \qquad (1)$$

where

$$BEN_i(z) = \frac{\sum_{j=1}^{N_{i,pur}(z)+N_{i,sal}(z)} \sum_{t=-20}^{-11} R_{i,j,t}(z)}{N_i(z)} \quad i = 1, \ldots, 28$$

and

$R_{i,j,t}(z) \equiv$ return for quote *t* relative to trade of interest *j* for maturity *i*,

$N_{i,pur}(z) \equiv$ number of purchases of size *z* for maturity *i*,

$N_{i,sal}(z) \equiv$ number of sales of size *z* for maturity *i* and

$N_i(z) \equiv$ total number of quotes for maturity *i* in the benchmark periods for all trades of size *z*.

Returns are computed using ask quote prices for purchases and bid quote prices for sales. Different benchmarks are computed for each trade size and for each contract maturity. For example, to compute mean excess returns relative to large block purchases, benchmark returns are first computed for each maturity using quotes -20 through -11 relative to all block trades for that maturity. Excess returns relative to the maturity-specific benchmark are averaged across all block purchases and across all maturities. The excess return for quote 0 relative to the trade of interest is defined as the excess return from the prevailing quote to the trade of interest. The excess return for quote +1 is defined as the excess return from the trade of interest to the outstanding quote after the trade of interest. Returns based on quoted prices defined in this manner are reported to illustrate the location of the trade of interest relative to the surrounding quotes and to measure the information impact on quoted prices directly.

Lee, Mucklow and Ready (1993) show that both bid-ask spreads and depth are needed to infer changes in liquidity unambiguously; changes in either spreads or depth alone could reflect movements along the liquidity supply curve rather than shifts in the position of the curve itself. Therefore, changes in both spreads and depth are examined to determine the characteristics of the liquidity adjustment surrounding large trades.

To measure liquidity, mean spreads relative to a purchase of interest are computed as

$$\overline{S}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)} S_{i,j,t}(z)}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \qquad (2)$$

where $S_{i,j,t}(z) \equiv$ quoted bid-ask spread in basis or index points (ask minus bid) for contract maturity i at quote t relative to the trade of interest j of size z. Using a methodology similar to that for excess returns, a benchmark spread series for each maturity is also constructed using the bid-ask spread for quotes -20 through -11 relative to all trades of size z. Mean excess spreads relative to purchases of size z during the sample period are computed as

$$\overline{RS}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)} [S_{i,j,t}(z) - BENSPR_i(z)]}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \qquad (3)$$

where

$$BENSPR_i(z) = \frac{\sum_{j=1}^{N_{i,pur}(z)+N_{i,sal}(z)} \sum_{t=-20}^{-11} S_{i,j,t}(z)}{N_i(z)} \quad i = 1, \ldots, 28$$

As a second measure of liquidity, mean depths relative to purchases of size z are computed as

$$\overline{D}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)} D_{i,j,t}(z)}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \qquad (4)$$

where $D_{i,j,t}(z) \equiv$ depth (defined as the ask depth relative to purchases and bid depth relative to sales, in number of contracts) for contract maturity i at quote t relative to the trade of interest j of size z. A benchmark depth series for each maturity is constructed using the depth for quotes -20 through -11 relative to all trades of size *z*. Mean excess depths relative to purchases are computed as

$$\overline{RD}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)}[D_{i,j,t}(z) - BENDEP_i(z)]}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = \text{-10, …, +20} \qquad (5)$$

where

$$BENDEP_i(z) = \frac{\sum_{j=1}^{N_{i,pur}(z)+N_{i,sal}(z)}\sum_{t=-20}^{-11} D_{i,j,t}(z)}{N_i(z)} \quad i = 1, …, 28$$

This methodology is used to compute benchmark and excess spread and depth statistics relative to small, medium and large purchases and sales.

3. Changes in the levels of bid and ask quoted prices

This section documents price effects following the execution of large market orders as measured by changes in bid and ask quoted prices. Figures 1 and 2 illustrate cumulative excess returns computed using ask quotes around purchases and bid quotes around sales respectively.[22] Table 2 reports mean excess returns computed using the same quoted prices, as defined in equation (1). The cumulative price changes (from quote -10 through quote +20 relative to the trade of interest) increase monotonically with the size of the purchase (figure 1) and decrease monotonically with the size of the sale (figure 2). These results are as predicted if trade size is correlated with information.

Traders exercise a degree of patience in executing small and medium-size trades that is not evident for block trades. Ask quotes decrease in price prior to the arrival of small and medium purchases and bid quotes increase in price prior to the arrival of small and medium sales. Small and medium trades take place when prices move to more favourable levels, suggesting that the demand to trade these sizes is relatively price elastic. Similar results are evident in the behaviour of quoted prices before NYSE-listed equity trades reported by Koski and Michaely (2000). This behaviour of quotes before trades also demonstrates that the price improvement process in financial markets is not confined to that offered by specialists in

[22] Also computed are revisions in bid quotes surrounding purchases and ask quotes surrounding sales, as well as mid-quote price changes surrounding purchases and sales. In each case, the results are almost identical to those reported in this article.

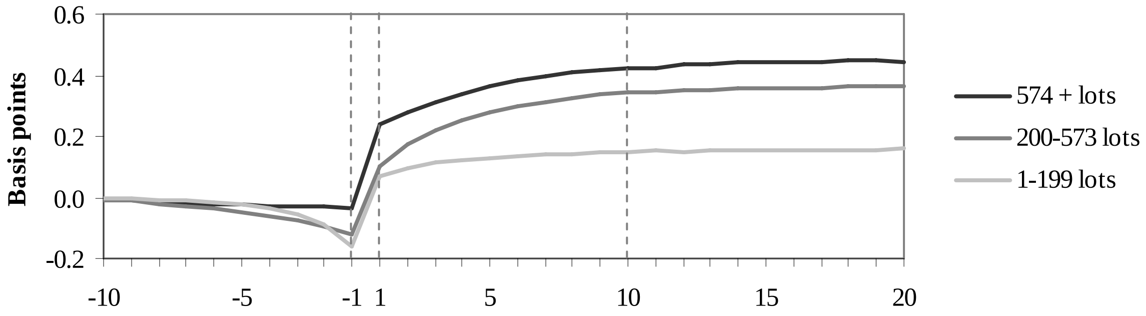
quote-driven dealer markets. In their quest to exploit a short-lived information advantage, traders appear to be less willing to wait until prices move to more favourable levels before placing large market orders and consequently the extent of price improvement before large block trades is relatively meagre.

Ask quotes are revised upwards in quote +1 after block purchases and continue to be revised upwards in subsequent quotes. Differences in the initial revisions (from the trade to the first quote after the trade) between small trades and blocks are highly statistically significant after purchases of all four contracts (see table 2). Initial price revisions do not appear to be overreactions that are subsequently corrected; there is little evidence of any substantial price recovery (except briefly in two subsequent quotes for SFE SPI 200™ futures). These results suggest that any temporary price effects due to transitory factors such as inventory control, search costs or temporary information effects are more than compensated by permanent price effects. Likewise, bid quotes are revised downwards in quote +1 after block sales and continue to be revised downwards in subsequent quotes. In contrast to previous findings from equity markets, the permanent price effects of block sales match the permanent price effects of block purchases, implying that there are at least as many informed sellers as informed buyers in futures markets.

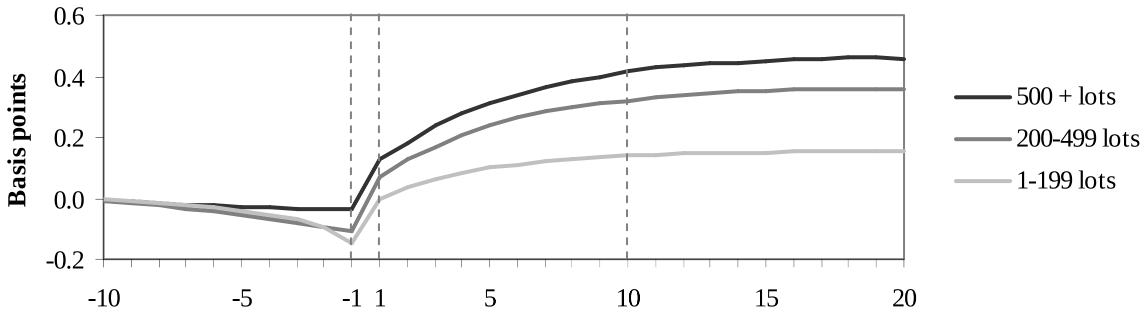
The price adjustment process is hastened by the speed of quote revisions after blocks. In quote update time, consecutive ask quote returns after block purchases are positive and significant for seven quotes for 90 day bank bill futures, twelve quotes for 3 year Treasury bond futures, eight quotes for 10 year Treasury bond futures and twelve quotes (following a slight recovery) for SFE SPI 200™ futures. In clock time, the results reported in appendix 1 imply that most of the price adjustment occurs within roughly 63 seconds for 90 day bank bill futures, 70 seconds for 3 year Treasury bond futures, 59 seconds for 10 year Treasury bond futures and 61 seconds for SFE SPI 200™ futures. Similar results are documented for block sales. These results are comparable with Kim and Sheen (2001) who find that the price adjustment in the Australian 10 year bond futures market to the scheduled release of macroeconomic information is concentrated in the first minute after release.

Figure 1
Cumulative excess quote returns surrounding purchases

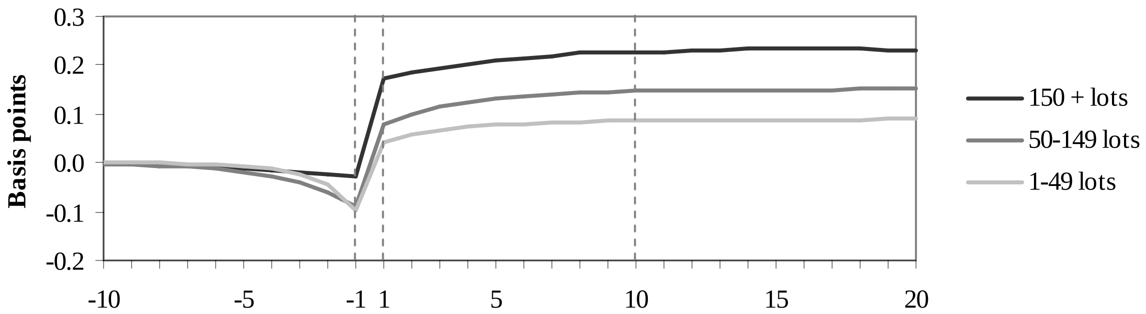
Panel A: 90 day bank bill futures



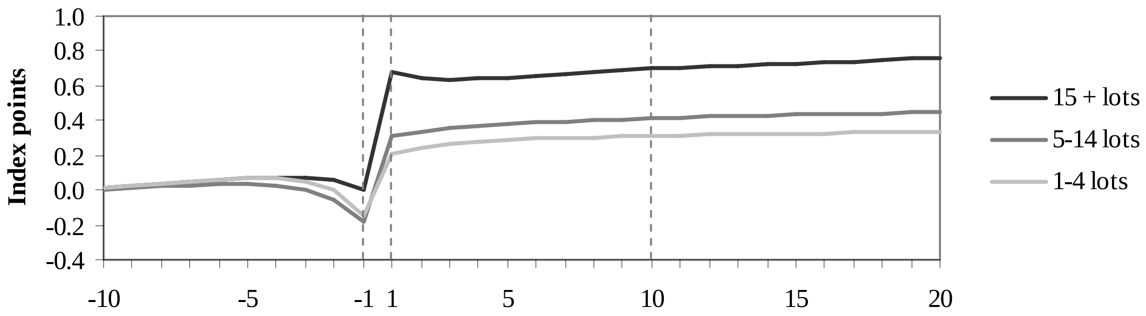
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



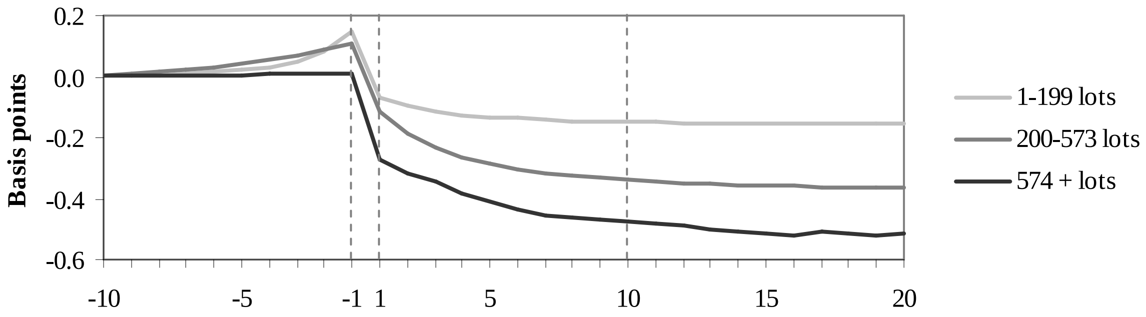
Panel D: SFE SPI 200™ futures



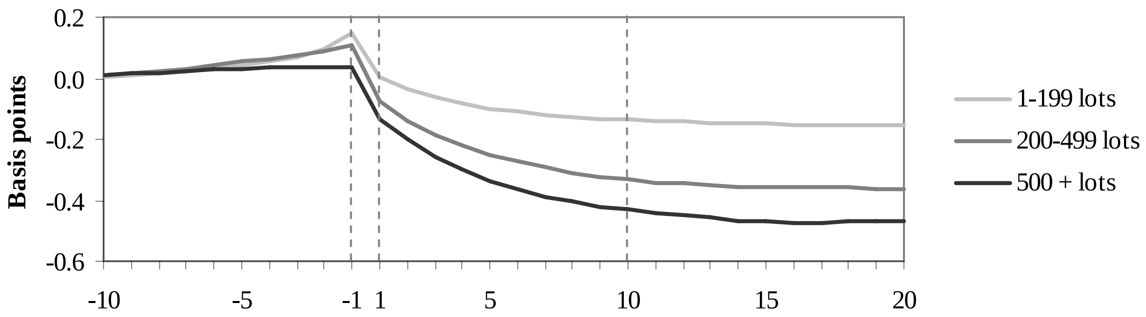
Cumulative excess returns based on quotation prices by quote relative to the purchase of interest (trade 0) for small, medium and large purchases.

Figure 2
Cumulative excess quote returns surrounding sales

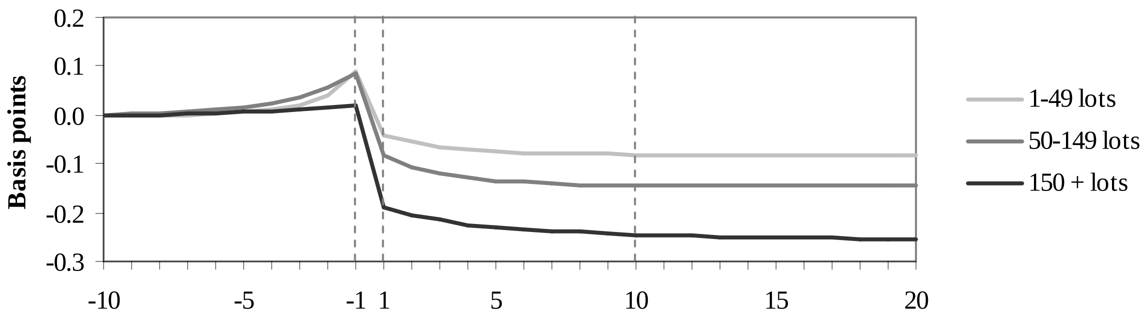
Panel A: 90 day bank bill futures



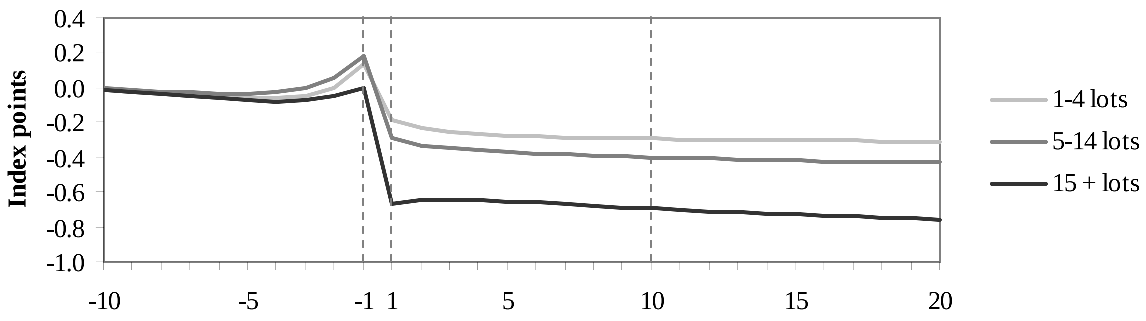
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



Panel D: SFE SPI 200™ futures



Cumulative excess returns based on quotation prices by quote relative to the sale of interest (trade 0) for small, medium and large sales.

Table 2
Quote excess returns by direction and size of trade

	Quote relative to trade of interest (trade 0)									
	Purchases					Sales				
Size of trade	**-2**	**-1**	**0**	**1**	**2**	**-2**	**-1**	**0**	**1**	**2**
Panel A: 90 day bank bill futures										
1-199 lots										
Mean	-0.033	-0.070	0.000	0.227	0.028	0.030	0.068	0.000	-0.221	-0.025
t: Mean = 0	-37.83	-76.84	8.37	174.73	28.16	35.62	77.54	-3.76	-168.70	-24.71
200-573 lots										
Mean	-0.018	-0.025	0.001	0.218	0.074	0.020	0.022	-0.002	-0.226	-0.069
t: Mean = 0	-11.97	-18.61	2.53	67.73	26.61	12.53	16.89	-5.40	-66.71	-24.06
574 + lots										
Mean	-0.002	-0.005	0.001	0.271	0.044	0.002	0.001	-0.003	-0.282	-0.042
t: Mean = 0	-1.56	-3.68	1.74	37.66	9.36	1.36	0.41	-2.73	-38.26	-8.81
Panel B: 3 year treasury bond futures										
1-199 lots										
Mean	-0.026	-0.051	0.000	0.145	0.038	0.026	0.050	0.000	-0.144	-0.039
t: Mean = 0	-53.13	-99.63	10.48	193.74	60.55	53.55	98.94	-0.91	-193.54	-62.65
200-499 lots										
Mean	-0.013	-0.013	0.001	0.175	0.056	0.014	0.014	-0.001	-0.179	-0.063
t: Mean = 0	-13.87	-16.75	4.76	73.32	29.06	13.57	17.72	-4.07	-73.98	-31.33
500 + lots										
Mean	-0.002	-0.002	0.001	0.166	0.055	0.001	0.002	-0.002	-0.171	-0.069
t: Mean = 0	-2.63	-3.10	3.44	46.04	21.25	0.73	3.38	-4.19	-46.37	-23.86

Table 2 *continued*

	Quote relative to trade of interest (trade 0)									
	Purchases					Sales				
Size of trade	**-2**	**-1**	**0**	**1**	**2**	**-2**	**-1**	**0**	**1**	**2**
Panel C: 10 year treasury bond futures										
1-49 lots										
Mean	-0.020	-0.054	0.001	0.139	0.015	0.019	0.051	0.000	-0.131	-0.014
t: Mean = 0	-48.16	-129.94	21.74	328.78	38.96	60.12	157.46	-12.14	-324.73	-40.98
50-149 lots										
Mean	-0.019	-0.032	0.001	0.166	0.023	0.020	0.031	-0.001	-0.167	-0.025
t: Mean = 0	-30.19	-53.90	13.07	137.53	25.02	30.30	51.22	-11.35	-159.36	-26.10
150 + lots										
Mean	-0.004	-0.004	0.002	0.195	0.013	0.004	0.005	-0.005	-0.201	-0.017
t: Mean = 0	-4.59	-6.49	7.76	91.76	8.34	4.39	6.60	-11.50	-91.25	-10.30
Panel D: SFE SPI 200^{TM} futures										
1-4 lots										
Mean	-0.049	-0.146	0.002	0.354	0.034	0.049	0.135	-0.002	-0.324	-0.042
t: Mean = 0	-117.10	-348.58	77.90	795.55	76.94	122.74	341.48	-64.28	-755.34	-100.29
5-14 lots										
Mean	-0.059	-0.122	0.013	0.470	0.034	0.060	0.118	-0.012	-0.459	-0.036
t: Mean = 0	-87.00	-190.88	91.35	599.23	42.12	90.67	188.47	-80.86	-583.88	-45.62
15 + lots										
Mean	-0.017	-0.052	0.070	0.600	-0.028	0.023	0.050	-0.078	-0.597	0.023
t: Mean = 0	-13.14	-42.49	83.61	362.10	-17.75	18.17	41.77	-86.73	-351.00	14.62

Excess returns by quote relative to small, medium and large trades. Quote-to-quote returns are computed from ask quote to ask quote for purchases and from bid quote to bid quote for sales. The excess return for quote 0 relative to the block trade is defined as the excess return from the prevailing quote to the block trade. The excess return for quote +1 is defined as the excess return from the block trade to the first quote after the block trade. *Mean* is the mean excess return in basis or index points. *t*: *Mean* = 0 is the *t*-statistic for the test of the null hypothesis that the mean excess return equals zero. Results are reported for 90 day bank bill futures (panel A), 3 year treasury bond futures (panel B), 10 year treasury bond futures (panel C) and SFE SPI 200^{TM} futures (panel D).

The results in this section suggest that large market orders are more often based on a short-lived trading advantage, derived from superior information processing skills.[23] Frino and Oetomo (2005) examine the price impact for packages of trades that are likely to belong to the same original orders executed in the same contracts analysed in this study. The trade packages they examine are typically executed over several hours or days.[24] They find little evidence that trade packages convey information (by the close of trading on the day after the package completely executes). The results presented here do not dispel the possibility that trade packages represent the portfolio rebalancing activities of large institutional investors, either to obtain desired hedging positions or based on long-lived information that is released into the public domain gradually over weeks and months. Unlike the portfolio rebalancing activities that could require patient execution over several days, trading to express divergent views on the meaning of public information is an activity that is resolved quickly (within a few trades). Hence, prices adjust sharply to block trades executed using market orders without recovering.

Further evidence relating to the source of the price effects associated with block trades is obtained by examining the liquidity adjustment around blocks. A persistent disruption to liquidity after block trades may indicate a temporary shift in the balance of market power from liquidity traders to informed traders, with liquidity providers straight away becoming uncertain about whether the block trade was based on information (Easley and O'Hara, 1987; Mann and Ramanlal, 1996).

4. Impact of trades on liquidity

This section analyses the systematic changes in quoted liquidity surrounding large-trade execution, as well as the time taken for liquidity to return to normal levels. The spread between the bid and ask prices is adopted as a measure of the price of liquidity and the depth at the best prevailing quotes is adopted as a measure of the quantity of liquidity that participants are willing to provide at the quoted price. The arrival of a block trade temporarily

[23] This is consistent with the finding of Kurov (2005) that customer limit orders in futures markets incur adverse selection costs.
[24] A limitation of the data set employed by Frino and Oetomo (2005) is that they are unable to distinguish whether trade packages are executed using market orders or limit orders. A follow-up study by Frino, Kruk and Lepone (2007) applying the trade package benchmarks to all individual trades in the package does not measure the price effects of large market orders because individual trades resulting from the same market order and executed against multiple limit orders are treated separately. Large market orders typically transact with several counterparties at a time, as shown in table 1.

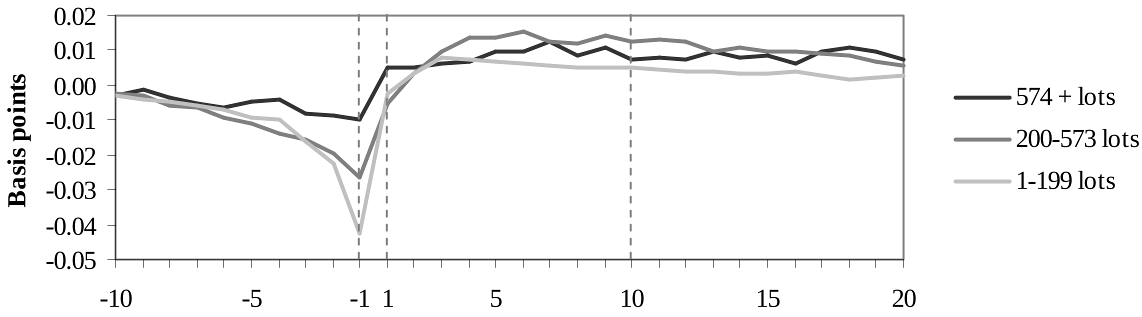
interrupts the supply of liquidity by consuming depth and potentially widening the spread. It could intensify the adverse selection problem if some market participants are better equipped to interpret the information signal provided by the block than others, which would obstruct or delay the recovery in liquidity (Hasbrouck, 1991; Lee, Mucklow and Ready, 1993; Koski and Michaely, 2000; Anderson, Cooper and Prevost, 2006). At the same time, if the arrival of the block trade excites the market, in the sense that it widens the disparity of views among traders about the intrinsic value of the contract, it could further stimulate the demand for immediacy and hasten the recovery in liquidity due to the intense competition between liquidity providers to meet the newly created excess demand.

To examine the adjustment in the price and quantity of market liquidity, figures 3 and 4 illustrate changes in excess bid-ask spreads [as defined in equation (3)] and figures 5 and 6 illustrate changes in excess depth [equation (5)] around purchases and sales of different sizes in each contract. Table 3 reports average spreads [equation (2)] and excess spreads and table 4 reports average depth [equation (4)] and excess depth as a function of trade size around purchases and sales.

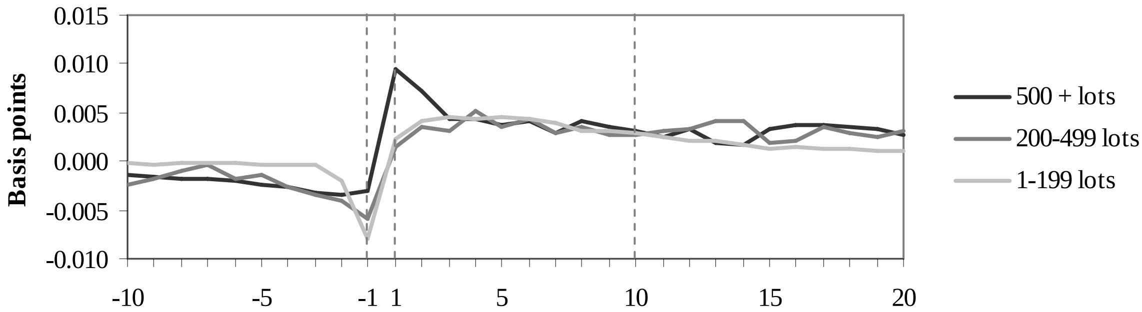
Excess bid-ask spreads immediately after block trades in the equity index contract are substantially larger than after block trades in the interest rate contracts (table 3). For example, the excess spread immediately after large block purchases of SFE SPI 200™ futures represents 6.1 percent of the minimum tick (of one index point). This value compares to excess spreads immediately after block purchases of 90 day bank bill futures of 0.5 percent of the minimum tick, immediately after block purchases of 3 year Treasury bond futures of 0.9 percent of the minimum tick and immediately after block purchases of 10 year Treasury bond futures of 2.0 percent of the minimum tick. Excess spreads are also larger immediately after block trades than immediately after small and medium trades. For example, the excess spread immediately after large block purchases of 90 day bank bill futures of 0.005 basis points compares to excess spreads immediately after medium purchases of -0.005 basis points and immediately after small purchases of -0.002 basis points. These differences are statistically significant (at the one percent level). Results show that spreads after block purchases remain wider for at least eighteen quotes for 90 day bank bill futures, twelve quotes for 3 year Treasury bond futures, fifteen quotes for 10 year Treasury bond futures and at least twenty quotes for SFE SPI 200™ futures. In clock time, the wider spreads persist for longer than one minute after block purchases of all four contracts. Similar results hold for block sales.

Figure 3
Excess bid-ask spreads surrounding purchases

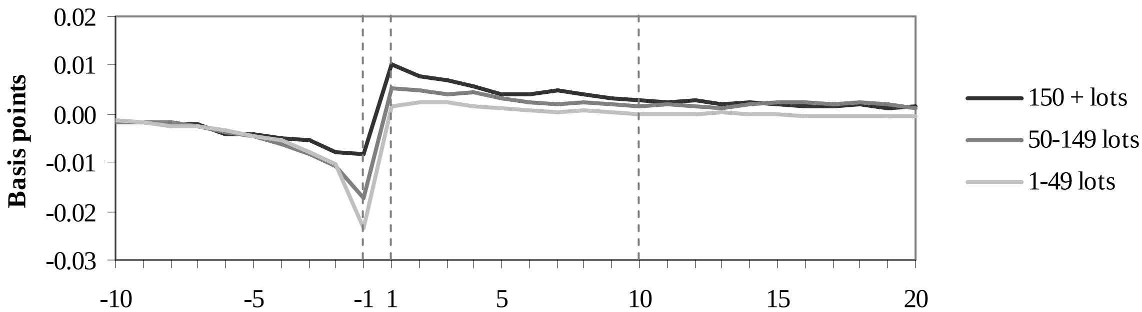
Panel A: 90 day bank bill futures



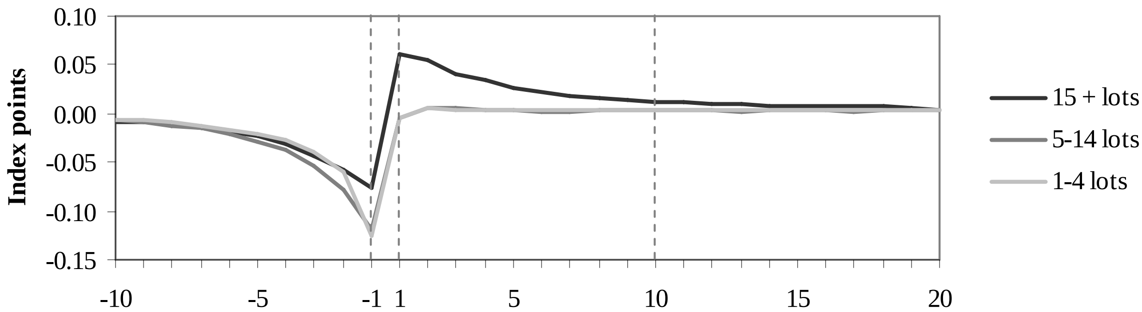
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



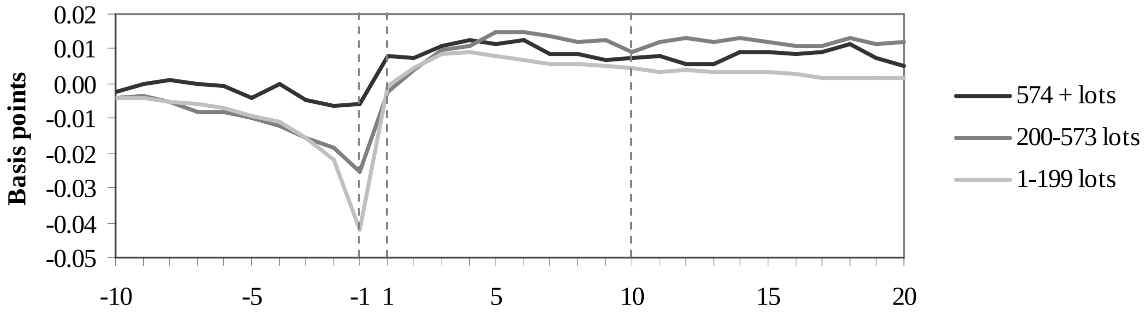
Panel D: SFE SPI 200™ futures



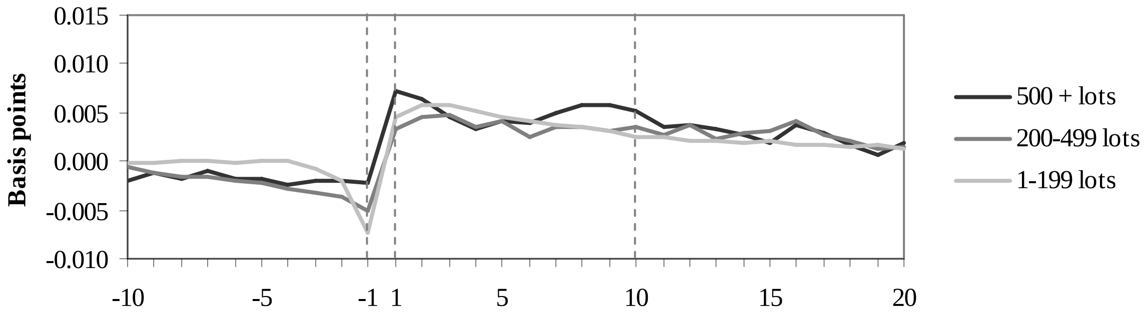
Excess bid-ask spreads relative to purchases of various sizes. Trade 0 represents the block trade of interest.

Figure 4
Excess bid-ask spreads surrounding sales

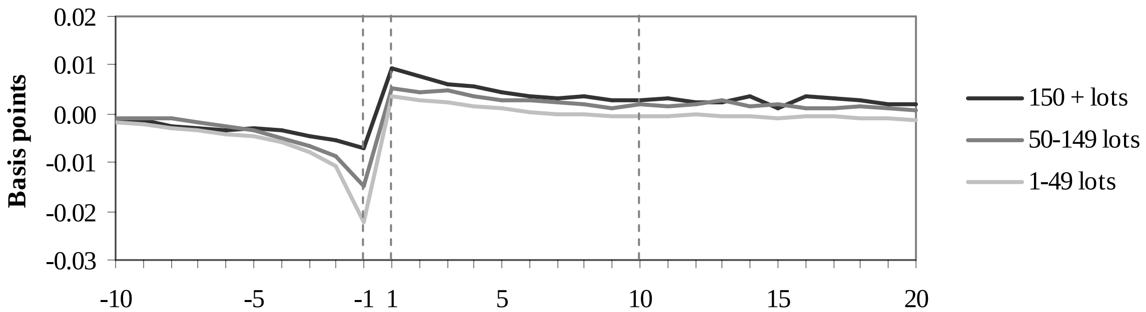
Panel A: 90 day bank bill futures



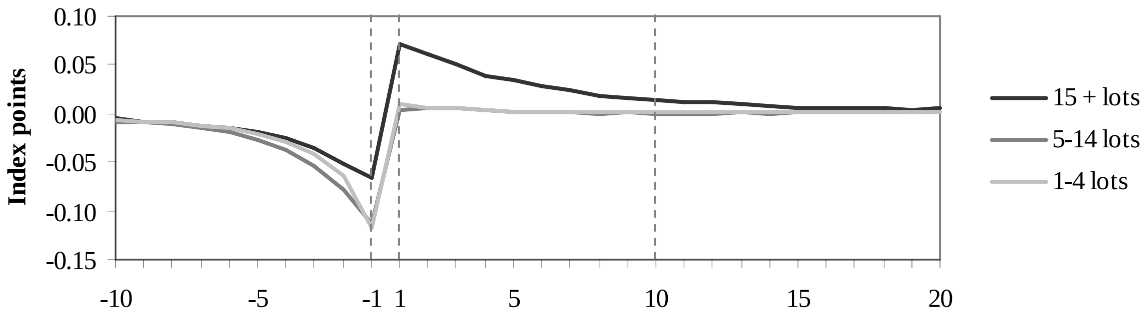
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



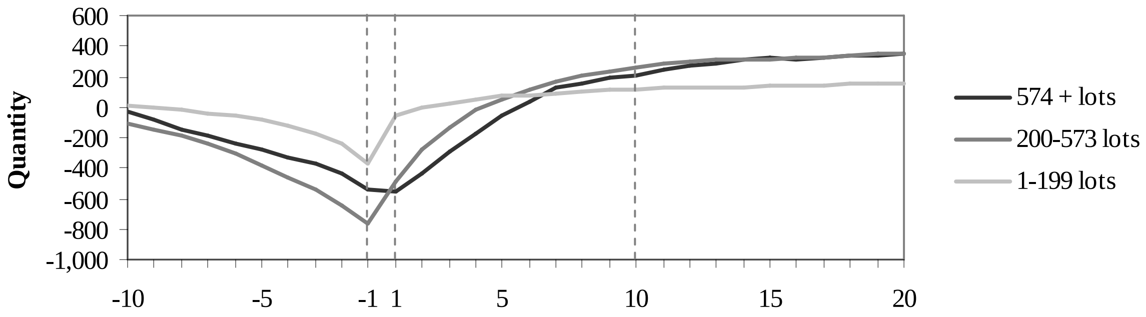
Panel D: SFE SPI 200™ futures



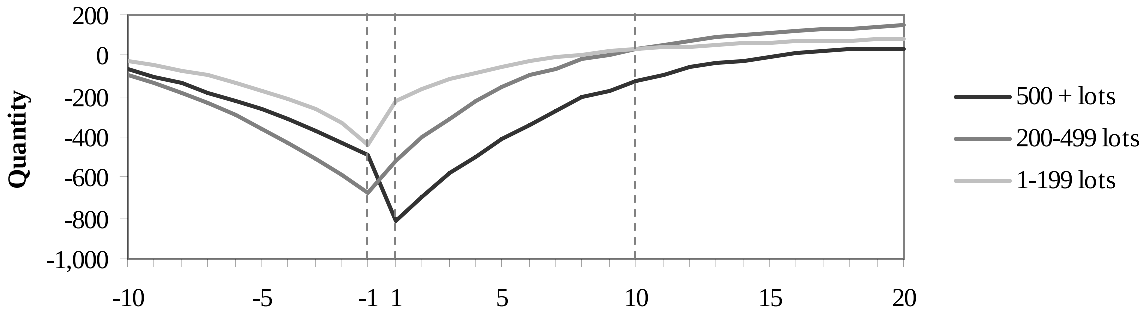
Excess bid-ask spreads relative to sales of various sizes. Trade 0 represents the block trade of interest.

Figure 5
Excess market depth surrounding purchases

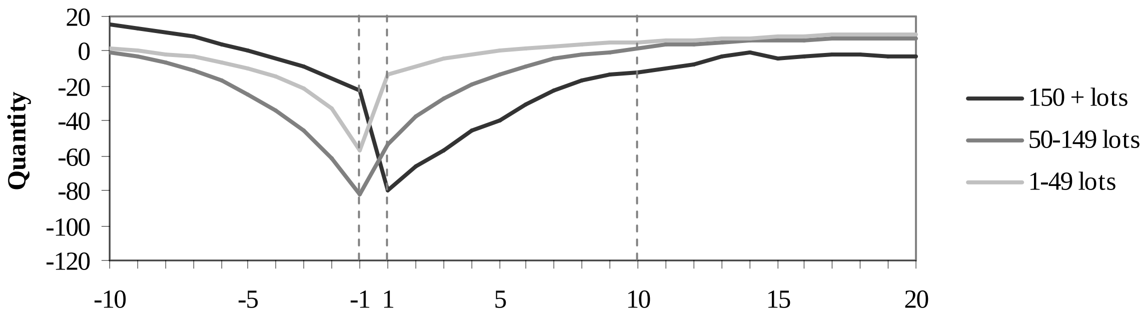
Panel A: 90 day bank bill futures



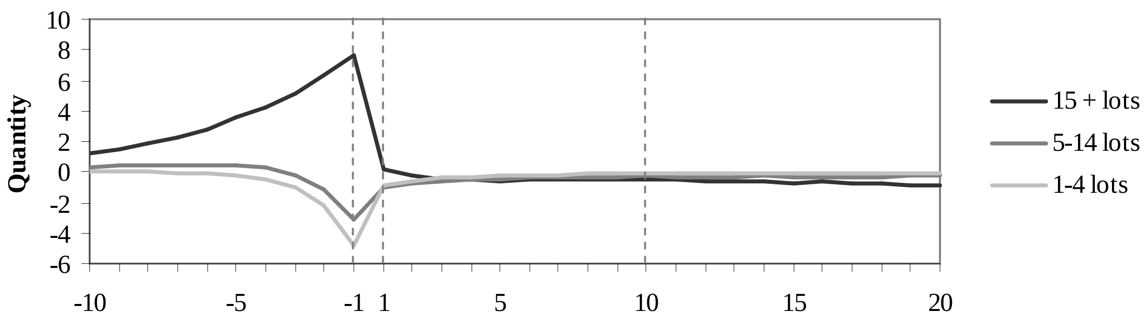
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



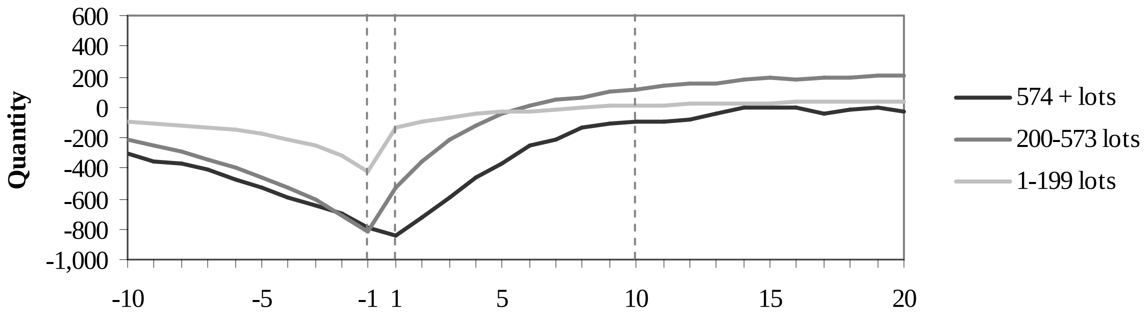
Panel D: SFE SPI 200™ futures



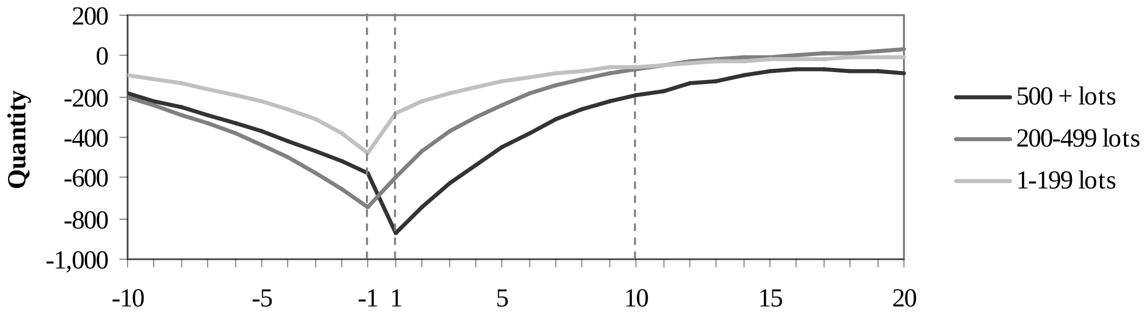
Excess market depth (ask quote depth) relative to purchases of various sizes. Depth is in number of contracts. Trade 0 represents the block trade of interest.

Figure 6
Excess market depth surrounding sales

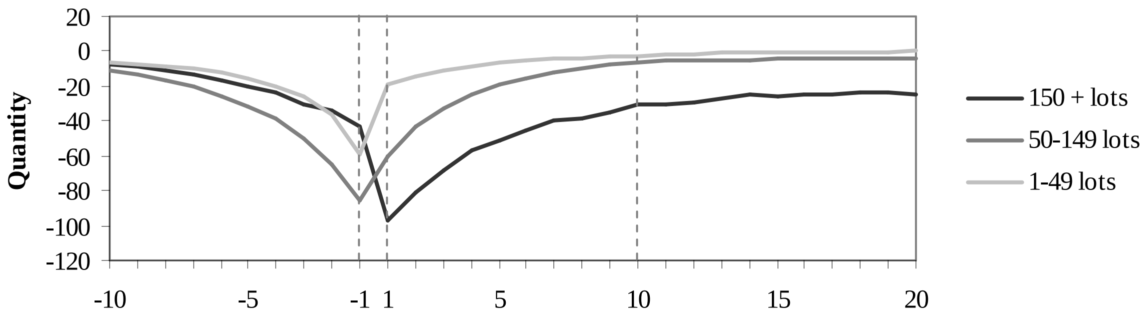
Panel A: 90 day bank bill futures



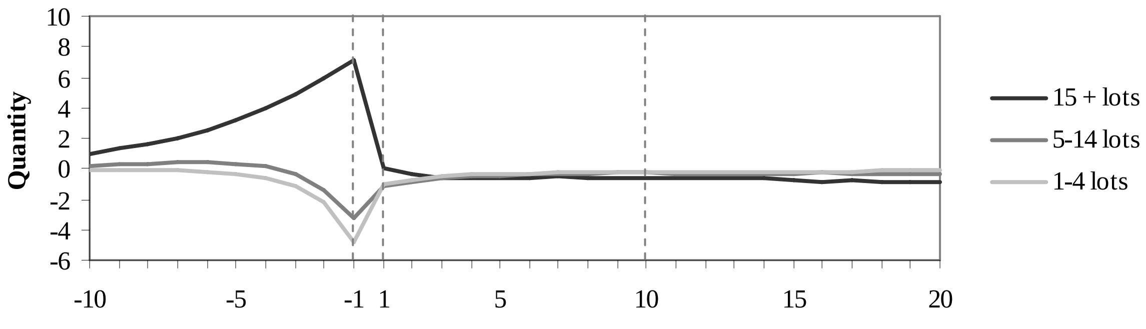
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



Panel D: SFE SPI 200™ futures



Excess market depth (bid quote depth) relative to sales of various sizes. Depth is in number of contracts. Trade 0 represents the block trade of interest.

Table 3
Bid-ask spreads by direction and size of trade

	Quote relative to trade of interest (trade 0)									
	Purchases					**Sales**				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel A: 90 day bank bill futures										
1-199 lots										
Mean spread	1.031	1.011	1.051	1.057	1.061	1.032	1.012	1.053	1.058	1.062
Mean excess spread	-0.023	-0.042	-0.002	0.003	0.008	-0.022	-0.042	-0.001	0.005	0.008
t: Excess spread = 0	-37.43	-105.16	-3.06	4.28	9.71	-36.95	-103.17	-0.67	5.52	10.20
200-573 lots										
Mean spread	1.013	1.006	1.027	1.035	1.042	1.014	1.007	1.030	1.036	1.042
Mean excess spread	-0.019	-0.027	-0.005	0.003	0.010	-0.019	-0.025	-0.002	0.004	0.010
t: Excess spread = 0	-17.00	-33.14	-3.77	2.05	5.96	-16.22	-28.47	-1.50	2.40	5.47
574 + lots										
Mean spread	1.003	1.002	1.017	1.017	1.018	1.006	1.006	1.020	1.019	1.023
Mean excess spread	-0.009	-0.010	0.005	0.005	0.006	-0.006	-0.006	0.008	0.007	0.011
t: Excess spread = 0	-8.62	-12.34	2.43	2.32	2.83	-3.82	-3.41	2.71	3.13	4.42
Panel B: 3 year treasury bond futures										
1-199 lots										
Mean spread	1.008	1.002	1.013	1.015	1.015	1.008	1.003	1.015	1.016	1.016
Mean excess spread	-0.002	-0.008	0.002	0.004	0.004	-0.002	-0.007	0.005	0.006	0.006
t: Excess spread = 0	-8.76	-57.31	8.79	15.57	16.44	-8.69	-47.70	16.42	20.45	19.92
200-499 lots										
Mean spread	1.004	1.002	1.009	1.011	1.011	1.004	1.003	1.011	1.012	1.012
Mean excess spread	-0.004	-0.006	0.001	0.004	0.003	-0.004	-0.005	0.003	0.005	0.005
t: Excess spread = 0	-8.21	-17.62	2.44	5.13	4.81	-6.68	-11.42	4.36	6.08	6.44
500 + lots										
Mean spread	1.001	1.001	1.014	1.011	1.009	1.002	1.002	1.012	1.011	1.009
Mean excess spread	-0.003	-0.003	0.009	0.007	0.004	-0.002	-0.002	0.007	0.006	0.005
t: Excess spread = 0	-12.47	-8.67	8.30	6.78	4.88	-3.11	-3.10	5.84	5.59	4.82

Table 3 *continued*

	Quote relative to trade of interest (trade 0)									
	Purchases					Sales				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel C: 10 year treasury bond futures										
1-49 lots										
Mean spread	0.520	0.507	0.532	0.533	0.533	0.519	0.507	0.533	0.533	0.532
Mean excess spread	-0.010	-0.024	0.001	0.003	0.002	-0.011	-0.022	0.004	0.003	0.002
t: Excess spread = 0	-33.08	-179.33	5.54	10.08	9.70	-54.72	-155.92	14.11	11.89	9.78
50-149 lots										
Mean spread	0.510	0.504	0.526	0.526	0.525	0.513	0.507	0.527	0.526	0.526
Mean excess spread	-0.011	-0.017	0.005	0.005	0.004	-0.009	-0.015	0.005	0.005	0.005
t: Excess spread = 0	-29.87	-69.90	6.65	6.15	5.41	-6.07	-10.43	9.41	8.38	8.70
150 + lots										
Mean spread	0.503	0.503	0.521	0.519	0.518	0.506	0.504	0.520	0.518	0.517
Mean excess spread	-0.008	-0.008	0.010	0.008	0.007	-0.005	-0.007	0.009	0.008	0.006
t: Excess spread = 0	-20.92	-22.21	10.05	8.38	7.63	-5.20	-15.57	9.29	7.93	6.55
Panel D: SFE SPI 200^{TM} futures										
1-4 lots										
Mean spread	1.139	1.073	1.193	1.203	1.203	1.135	1.081	1.209	1.205	1.204
Mean excess spread	-0.059	-0.126	-0.005	0.005	0.005	-0.064	-0.118	0.011	0.006	0.006
t: Excess spread = 0	-181.10	-503.06	-12.69	13.70	11.79	-202.84	-461.15	27.69	16.82	14.72
5-14 lots										
Mean spread	1.095	1.054	1.168	1.179	1.178	1.094	1.059	1.177	1.178	1.178
Mean excess spread	-0.078	-0.119	-0.005	0.006	0.005	-0.078	-0.113	0.005	0.006	0.005
t: Excess spread = 0	-167.60	-327.65	-8.42	9.52	7.63	-168.98	-301.12	7.17	8.86	8.52
15 + lots										
Mean spread	1.088	1.070	1.208	1.202	1.187	1.095	1.080	1.219	1.209	1.197
Mean excess spread	-0.059	-0.077	0.061	0.055	0.041	-0.052	-0.067	0.071	0.062	0.050
t: Excess spread = 0	-64.69	-94.53	40.58	37.64	28.67	-54.43	-75.42	45.81	40.30	33.95

Summary statistics regarding bid-ask spreads for quotes relative to small, medium and large trades. *Mean spread* is the mean bid-ask spread in basis or index points. Excess spreads are spreads in excess of a benchmark level, computed using spreads -20 through -11 relative to trades of a given size. For excess spreads, reported results include *Mean excess spread* and *t: Excess spread = 0* (the *t*-statistic for the test of the null hypothesis that the mean excess spread equals zero). Results are reported for 90 day bank bill futures (panel A), 3 year treasury bond futures (panel B), 10 year treasury bond futures (panel C) and SFE SPI 200^{TM} futures (panel D).

Table 4
Depth by direction and size of trade

	Quote relative to trade of interest (trade 0)									
	Purchases					**Sales**				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel A: 90 day bank bill futures										
1-199 lots										
Mean depth	1,441.8	1,320.2	1,633.5	1,677.4	1,710.0	1,350.2	1,236.6	1,528.1	1,568.7	1,595.5
Mean excess depth	-242.5	-364.1	-50.9	-6.9	25.6	-313.8	-427.4	-135.8	-95.3	-68.5
t: Excess depth = 0	-39.81	-60.47	-8.17	-1.11	4.08	-56.84	-77.72	-24.10	-16.87	-12.11
200-573 lots										
Mean depth	1,298.8	1,172.0	1,458.4	1,668.6	1,808.4	1,191.0	1,083.6	1,377.8	1,549.2	1,687.4
Mean excess depth	-643.4	-770.2	-483.8	-273.7	-133.9	-715.2	-822.7	-528.5	-357.1	-218.9
t: Excess depth = 0	-46.53	-58.41	-29.94	-15.88	-7.47	-57.56	-67.35	-34.03	-21.76	-12.87
574 + lots										
Mean depth	2,725.1	2,624.6	2,609.2	2,726.7	2,875.2	2,522.4	2,433.7	2,383.5	2,508.0	2,632.2
Mean excess depth	-442.6	-543.1	-558.4	-440.9	-292.5	-704.1	-792.8	-843.0	-718.4	-594.3
t: Excess depth = 0	-10.64	-13.39	-11.27	-8.81	-5.69	-19.43	-22.27	-20.28	-16.72	-13.30
Panel B: 3 year treasury bond futures										
1-199 lots										
Mean depth	1,175.7	1,069.6	1,283.7	1,343.5	1,390.2	1,122.5	1,021.6	1,221.1	1,276.9	1,317.4
Mean excess depth	-331.8	-437.8	-223.7	-163.9	-117.2	-378.5	-479.4	-280.0	-224.1	-183.6
t: Excess depth = 0	-116.99	-154.49	-77.06	-56.04	-39.93	-148.33	-187.44	-107.45	-85.43	-69.78
200-499 lots										
Mean depth	1,087.4	1,001.9	1,159.1	1,279.0	1,368.8	1,008.7	917.6	1,068.8	1,196.7	1,292.6
Mean excess depth	-588.9	-674.4	-517.2	-397.3	-307.5	-652.7	-743.8	-592.7	-464.8	-368.9
t: Excess depth = 0	-77.61	-89.61	-58.97	-43.03	-32.32	-93.54	-107.37	-73.06	-54.57	-42.20
500 + lots										
Mean depth	1,866.5	1,804.7	1,481.4	1,600.9	1,718.2	1,767.8	1,700.3	1,412.2	1,535.1	1,660.1
Mean excess depth	-425.9	-487.7	-811.1	-691.5	-574.2	-513.8	-581.3	-869.5	-746.6	-621.5
t: Excess depth = 0	-30.16	-34.73	-51.92	-42.18	-33.75	-39.64	-45.01	-59.32	-48.69	-39.07

Table 4 *continued*

	Quote relative to trade of interest (trade 0)									
	Purchases					Sales				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel C: 10 year treasury bond futures										
1-49 lots										
Mean depth	152.2	127.6	171.8	176.6	180.7	151.7	129.1	168.7	173.0	176.5
Mean excess depth	-32.8	-57.4	-13.2	-8.4	-4.3	-36.0	-58.6	-19.1	-14.7	-11.3
t: Excess depth = 0	-86.98	-154.52	-33.72	-21.36	-10.90	-105.94	-173.28	-54.73	-41.91	-32.00
50-149 lots										
Mean depth	192.2	170.6	199.3	215.7	226.5	184.7	163.9	189.5	206.2	216.3
Mean excess depth	-60.9	-82.5	-53.9	-37.4	-26.7	-64.7	-85.5	-59.9	-43.2	-33.1
t: Excess depth = 0	-64.55	-91.35	-49.11	-33.31	-23.32	-73.91	-101.59	-60.04	-42.22	-31.76
150 + lots										
Mean depth	382.7	375.6	318.3	332.6	341.3	370.0	361.0	307.4	323.7	336.5
Mean excess depth	-15.7	-22.8	-80.1	-65.8	-57.1	-34.4	-43.3	-97.0	-80.6	-67.8
t: Excess depth = 0	-6.62	-9.93	-28.34	-22.60	-19.38	-14.87	-19.23	-36.09	-29.16	-24.12
Panel D: SFE SPI 200^{TM} futures										
1-4 lots										
Mean depth	12.1	9.4	13.5	13.7	13.9	12.1	9.5	13.3	13.6	13.8
Mean excess depth	-2.2	-4.9	-0.8	-0.6	-0.4	-2.2	-4.8	-1.0	-0.7	-0.5
t: Excess depth = 0	-134.61	-308.86	-49.67	-35.00	-24.02	-168.59	-389.20	-75.28	-46.31	-34.75
5-14 lots										
Mean depth	15.2	13.3	15.5	15.7	15.8	15.1	13.2	15.4	15.6	15.8
Mean excess depth	-1.2	-3.1	-1.0	-0.7	-0.6	-1.4	-3.2	-1.1	-0.9	-0.7
t: Excess depth = 0	-39.09	-110.04	-29.35	-21.52	-19.06	-53.67	-156.51	-41.75	-30.82	-22.73
15 + lots										
Mean depth	28.0	29.3	21.9	21.5	21.2	27.6	28.9	21.7	21.3	21.1
Mean excess depth	6.3	7.6	0.2	-0.2	-0.5	6.0	7.2	0.0	-0.4	-0.6
t: Excess depth = 0	88.30	104.05	2.84	-2.37	-7.05	63.36	89.36	0.42	-4.92	-9.09

Summary statistics regarding depth for quotes relative to small, medium and large trades. Depth is defined as the ask quote depth relative to purchases and bid quote depth relative to sales. *Mean depth* is the mean depth in number of contracts. Excess depth is depth in excess of a benchmark level, computed using depth for quotes -20 through -11 relative to trades of a given size. For excess depth, reported results include *Mean excess depth* and *t: Excess depth = 0* (the *t*-statistic for the test of the null hypothesis that the mean excess depth equals zero). Results are reported for 90 day bank bill futures (panel A), 3 year treasury bond futures (panel B), 10 year treasury bond futures (panel C) and SFE SPI 200^{TM} futures (panel D).

Bid-ask spreads narrow significantly prior to trades and excess spreads immediately before trades are strongly related to trade size for all four contracts; the smaller the trade size, the further the spread narrows. This confirms that part of the price improvement before small and medium trades discussed in the previous section results from new limit orders placed inside the spread. Small and medium trades tend to occur when the cost for immediate execution of small and medium quantities cheapens momentarily. These results are also consistent with the evidence provided by Biais, Hillion and Spatt (1995) that investors in equities tend to hit the quote when the spread is tight, consuming liquidity when it is relatively inexpensive.[25]

Small temporary increases in bid-ask spreads after block trades suggest that block trades increase the adverse selection problem to a degree. The arrival of a block trade creates uncertainty about whether the trader is informed and whether private information based on superior information processing skills exists, as modelled by Easley and O'Hara (1987). The impact of block trades on spreads is much less prominent for the contracts that are the most liquid, in terms of the average depth at the best prevailing quotes and the average dollar value per trade.[26] This finding is consistent with Mann and Ramanlal's (1996) prediction that the adverse selection component of the bid-ask spread decreases as the size quotes increase. For very liquid markets where the size quotes are much larger than the minimum permissible, they expect the adverse selection component not to contribute significantly toward the total spread. This appears to be the case for the most liquid contracts in the sample; spreads for the interest rate contracts remain close to the minimum tick after block trades. The impact on depth, in these cases, is expected to be more revealing of market liquidity.

Changes in depth around individual trades (table 4) are far more pronounced than changes in spreads. Large trades cause a decrease in liquidity as measured by depth. For example, the ask quote depth drops from 1,804.7 lots to 1,481.4 lots after large block purchases of 3 year Treasury bond futures. These changes are highly statistically significant for purchases and

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[25] Likewise, Ding and Charoenwong (2003) find that an increase in the number of quote revisions increases the likelihood of a transaction in three thinly traded contracts on the Singapore Exchange—Nikkei 300 Stock Index futures, Dow Jones Thailand Index futures and MSCI Hong Kong Index futures contracts. When trading occurs in a day, both the number of quote revisions and the number of trades are negatively correlated with spreads.
[26] For the entire sample, the average value of the depth at the best prevailing quote immediately before trades is A$1,276.7 million for 90 day bank bill futures, A$108.8 million for 3 year Treasury bond futures, A$14.7 million for 10 year Treasury bond futures and A$1.3 million for SFE SPI 200™ futures. In comparison, the average trade sizes are A$102.0 million for 90 day bank bill futures, A$9.3 million for 3 year Treasury bond futures, A$3.0 million for 10 year Treasury bond futures and A$0.5 million for SFE SPI 200™ futures. These depths and order sizes are positively correlated across the contracts, as predicted by Mann and Ramanlal's (1996) information model that incorporates quoted depth.

sales of each contract, except 90 day bank bill futures. Depth decreases from abnormally low levels prior to the block for the interest rate contracts and from abnormally high levels prior to the block to slightly above normal levels immediately after the block for the equity index contract. Depth after block purchases remains below normal levels in four quotes for 90 day bank bill futures, twelve quotes for 3 year Treasury bond futures and eleven quotes for 10 year Treasury bond futures. In clock time, the recovery in depth after block purchases occurs within roughly 34 seconds for 90 day bank bill futures, 79 seconds for 3 year Treasury bond futures and 111 seconds for 10 year Treasury bond futures. These recovery times are realised even with the onset of more intense trading activity after blocks. In contrast to the interest rate contracts, the depth after block purchases of SFE SPI 200™ futures decreases to abnormally low levels in the third quote after the block and does not recover within twenty quotes. These findings highlight that market resiliency as measured by the time taken for both spreads and depth to return to previous levels varies considerably from contract to contract.

Lower depth on the bid side could indicate that liquidity providers face greater adverse selection risk from large block sales than from large block purchases. The bid depth prior to block sales is lower than the ask depth prior to block purchases and remains lower after block sales (these differences are statistically significant for all the contracts before blocks and the three interest rate contracts after blocks). Recovery times are also slower after block sales; depth remains below benchmark levels in eight quotes (lasting roughly 100 seconds) for 90 day bank bill futures and does not recover within twenty quotes for the other contracts. In addition to the direction of trade initiation, the relative size of the trade also appears to have a major effect on the liquidity return. In contrast to the results discussed above for large trades, depth increases from abnormally low levels prior to small and medium trades.[27] This confirms the results discussed in the previous section; small and medium trades tend to be executed when a small amount of depth is available at improved prices and with tightened bid-ask spreads.

As Moulton (1998) finds for NYSE-traded equities, results in this section suggest that security-specific attributes such as the risk profile, trading activity and initial spread widths have a profound influence on the form of liquidity disruption and the return of liquidity to previous levels. The size quotes posted by liquidity providers after block trades appear to

[27] Increases in depth immediately after small and medium trades reflect the fact that these trades clean out outstanding limit orders at the best prevailing quotes, revealing greater depth at higher ask prices for purchases and lower bid prices for sales.

play a more important role in futures markets than in equity markets. In the highly liquid interest rate markets, the liquidity adjustment surrounding large trades occurs almost exclusively through changes in quoted depth levels with minimal impact on the bid-ask spread. In the equity index market, however, there is also a sizeable impact on the spread. The changes in spreads and depth around equity index futures trades on the SFE more closely resemble those around equity trades on the NYSE analysed by Koski and Michaely (2000). In the equity market, they find that spreads increase significantly and depths decrease significantly after large trades although changes in depth are not as strong as the changes in spreads. The results for the equity index contract are also consistent with Lee, Mucklow and Ready (1993), who find that spreads widen and depths drop in response to volume shocks in equity markets. The findings from previous research based on equity markets appear to reflect the greater market power of informed traders and higher risk of private information, driving lower baseline liquidity levels, in equity markets relative to interest rate and equity index futures markets.

In the context of a limit-order driven futures market, liquidity providers respond to the information contained in trades in several ways consistent with Mann and Ramanlal's (1996) theoretical model of a competitive dealership market. Limit order traders lower their size quotes, rather than widen the bid-ask spread, as a first response to the decrease in market liquidity caused by a block trade. For that reason, changes in depth are much stronger than changes in spreads after large block trades in the interest rate contracts.[28] Only when the size quotes are close to the minimum do liquidity providers respond to the incremental decrease in market liquidity by widening the bid-ask spread. Accordingly, the market depth for the equity index contract does not drop substantially below its normal (relatively dry) level after block trades; instead liquidity providers widen spreads slightly as an additional tactic to offset expected losses to informed traders. In subsequent quotes for the equity index contract, spreads begin recovering sooner while depths remain slightly below normal levels.

[28] In keeping with Mann and Ramanlal's (1996) model, the recovery in depth on the active side of the limit order book after block trades in the interest rate contracts reaffirms the price continuation following blocks observed for these contracts. Mann and Ramanlal find that the asymmetry of the size quotes for buy and sell orders reveals the likely location of the equilibrium asset value relative to the bid and ask prices: the 'true' value drifts toward the ask (bid) price as the size quote at the ask (bid) increases relative to the size quote at the bid (ask), as dealers update their beliefs based on the type and size of incoming orders. Therefore, the true value drifts toward the ask (bid) price as the depth at the ask (bid) recovers following a block purchase (sale); representing continued price increases (decreases).

The results provide broad support for the conjecture that the liquidity cost of a large futures trade, over and above the bid-ask spread as constrained by the minimum tick, is mainly a pecuniary externality borne by other traders by impairing their continued ability to trade. There are insufficient price reversals following block trades to compensate liquidity providers for the adverse selection, inventory control and search costs they incur in absorbing and remarketing the block. Liquidity providers refrain from posting dramatically wider spreads, even for the least liquid contracts, given the competitive structure for market-making in futures markets. Locals appear to maintain lower size quotes for up to two minutes after block trades to manage the adverse selection problem and protect themselves against unwanted inventory. The lower depth affects those traders who require immediacy by ensuring any market orders they submit for large quantities transact at inferior prices until the depth recovers.[29]

Diminished depths on the active side of the limit order book after block trades, met by consecutive trades in the same direction (as shown in appendix 2), appear to contribute to the continued price increases following block purchases and continued price decreases following block sales of 90 day bank bill futures and 3 year Treasury bond futures, in particular.[30] For as long as liquidity providers maintain lower size quotes on the active side of the limit order book to manage the adverse selection problem, the size quote asymmetry indicates that informed trades are more likely to occur on the active side versus the passive side (Mann and Ramanlal, 1996). The continued downward price drift while the bid depth remains at abnormally low levels following block sales is consistent with the evidence from equity markets provided by Huang and Stoll (1994) that quote returns tend to be negative when depth at the bid is lower than depth at the ask. For the interest rate futures contracts, prices tend to stabilise just as depths recover on the active side of the limit order book.

[29] When liquidity providers maintain lower size quotes after block trades, informed traders' profits are lowered. Lowering their profits potentially benefits liquidity traders because competition among liquidity providers drives their profits toward zero (Mann and Ramanlal, 1996). Therefore, liquidity traders could be indirect beneficiaries of the liquidity externality that impairs the ability of informed traders to submit market orders at the time they possess more accurate information.

[30] The sizeable price drift for the interest rate contracts is consistent with the prediction of Easley and O'Hara (1992a) that while large market depth enhances efficiency in the short run, it slows the adjustment of prices to the underlying value of the security.

5. Conclusion

Futures markets are found to respond to the information content of large individual trades. Prices increase after block purchases and decrease after block sales without recovering, leaving permanent price effects that are positively related to the size of the block. The permanent price effects of block sales match the permanent price effects of block purchases, implying there are as many informed sellers as informed buyers in futures markets. The signed price change continues over several quote revisions before prices stabilise roughly one minute after the block strikes the order book. So neither the compensation rationale nor the orderly market hypothesis appears to be supported in futures markets; liquidity providers do not receive price concessions on post-block trades and there is little incentive for them to restrict the size of sequential price changes. Furthermore, there are insufficient price reversals following block trades to compensate liquidity providers for the adverse selection, inventory control and search costs they incur in absorbing and remarketing the block.

Large block trades produce a marked disruption to liquidity. Bid-ask spreads increase significantly and depth decreases significantly after large market orders are executed. In the market adjustment around large trades, the size quotes posted by liquidity providers are found to play a more important role in futures markets than in equity markets. The adjustment in market liquidity occurs primarily through changes in quoted depth levels for the interest rate and equity index futures contracts in the sample. Large trades also have a sizeable impact on the bid-ask spread for the equity index contract, similar to that reported by Koski and Michaely (2000) for NYSE-listed equities. Liquidity returns to previous levels more quickly for the futures contracts that are written over short and medium-term interest rates and that are the most liquid, in terms of the average trade size and the average depth at the best prevailing quotes. These findings are consistent with Moulton (1998), who finds that the return of liquidity to base levels is significantly related to security-specific attributes such as the risk profile of the underlying asset, trading activity and spread width.

Block trades appear to intensify the adverse selection problem, with some market participants better equipped than others to interpret the information signal provided by a block. The adverse selection problem is evident in the elevated price volatility, flurry of quote revisions and disruption to market liquidity prompted by block trades. The liquidity adjustment results also suggest that there is greater information asymmetry around block sales than around block purchases of the four contracts analysed in this study. As predicted by Mann and

Ramanlal (1996), limit order traders lower their size quotes, rather than widen the bid-ask spread, as a first response to the decrease in market liquidity caused by a block trade. For the interest rate contracts, locals appear to maintain lower size quotes for up to two minutes to manage the adverse selection problem and protect themselves against unwanted inventory. Only when the size quotes drop to minimum threshold levels after block trades, as is the case for the equity index contract, do they resort to wider spreads. Subsequently, spreads are much sooner to begin recovering than market depth in this case. These liquidity supply responses indicate that the liquidity cost of a large futures trade is mainly a pecuniary externality borne by other traders by impairing their continued ability to trade. Prices are only inclined to stabilise as this liquidity externality evaporates and the new information in the block is worked into quote prices incrementally over several limit order amendments.

In futures markets, the speed of adjustment in response to *unscheduled* large trades is as rapid as Ederington and Lee (1995) and Kim and Sheen (2001) report it is in response to new information relevant for bond pricing contained in *scheduled* macroeconomic announcements. The market response to block trades exhibits several features in common with the two-phase response of the United States Treasury market to the arrival of public information portrayed by Fleming and Remolona (1999). In particular, (i) there is a lull in trading activity up to the time the block trade arrives; (ii) prices adjust sharply to the block; (iii) the moments in which prices adjust sharply are accompanied by a marked disruption to liquidity; (iv) the sharp initial price change is followed by a surge in trading volume that persists along with high price volatility; and (v) liquidity returns to normal levels once a consensus price is reached. Most market participants seem to draw similar price implications from the unexpected component of a block trade, so that the initial price adjustment reflects a large common component in the shift in participants' expectations. The precise implication of each block is open to interpretation, however, which differs among traders depending on their analytical ability and customer order flows. The residual disagreement among traders provides the catalyst for the surge in trading volume together with the high volatility and disruption to liquidity after blocks, in the same way that Fleming and Remolona describe for macroeconomic announcements. The recovery in liquidity accelerates as the initial uncertainty about whether the block is based on information begins to subside and liquidity providers respond to the increased demand for immediacy post-block.

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Appendix 1

Information and volatility of bid and ask quoted prices

This appendix describes some additional characteristics of the quote revisions surrounding the main sample of trades. The speed of adjustment tests are supplemented by examining how much the volatility of quote-to-quote returns increases and how quickly quotes are revised after block transactions.

Figures A1.1 and A1.2 illustrate how quickly the quote-to-quote absolute returns revert to normally observed price movements after small, medium and large trades. A benchmark volatility series is constructed for each contract maturity from the absolute returns for quotes -20 through -11 relative to all trades of size *z*. Mean excess volatilities relative to purchases of size *z* during the sample period are computed as

$$\overline{RA}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)}[A_{i,j,t}(z) - BENABS_i(z)]}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \qquad \text{(A1.1)}$$

where

$$BENABS_i(z) = \frac{\sum_{j=1}^{N_{i,pur}(z)+N_{i,sal}(z)}\sum_{t=-20}^{-11} A_{i,j,t}(z)}{N_i(z)} \quad i = 1, \ldots, 28$$

and

$A_{i,j,t}(z) \equiv$ absolute return for quote t relative to trade of interest j for maturity i,

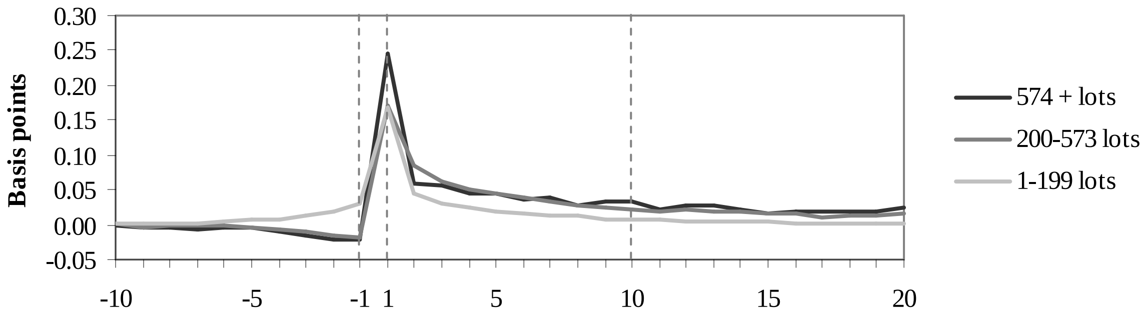
$N_{i,pur}(z) \equiv$ number of purchases of size z for maturity i,

$N_{i,sal}(z) \equiv$ number of sales of size z for maturity i and

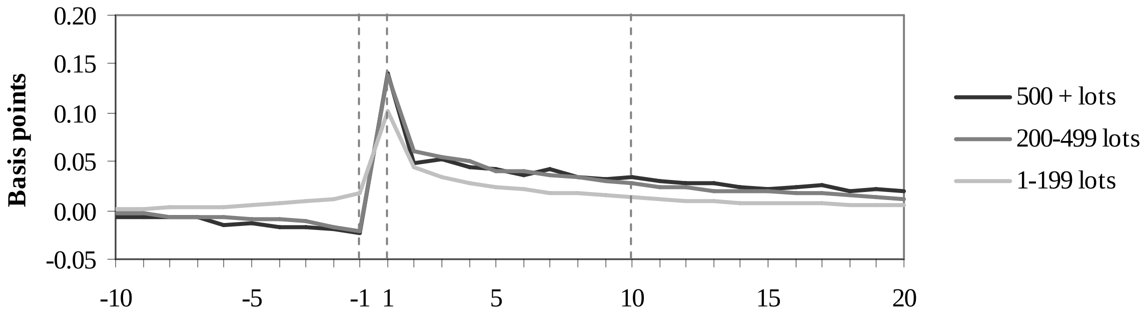
$N_i(z) \equiv$ total number of quotes for maturity i in the benchmark periods for all trades of size z.

Figure A1.1
Excess quote volatility surrounding purchases

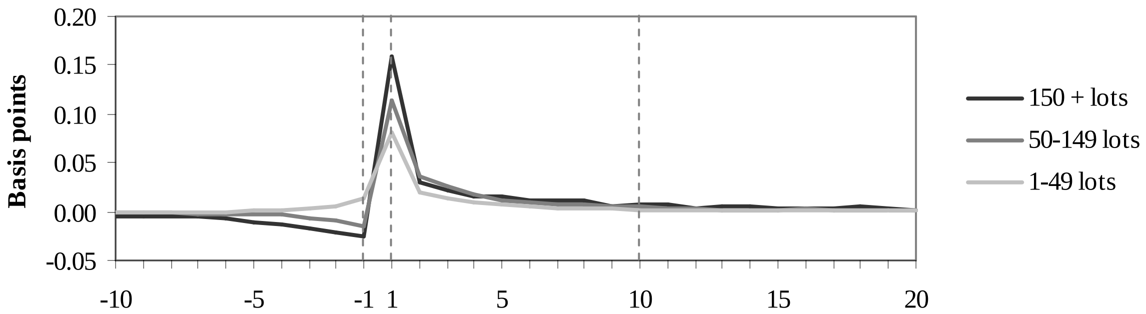
Panel A: 90 day bank bill futures



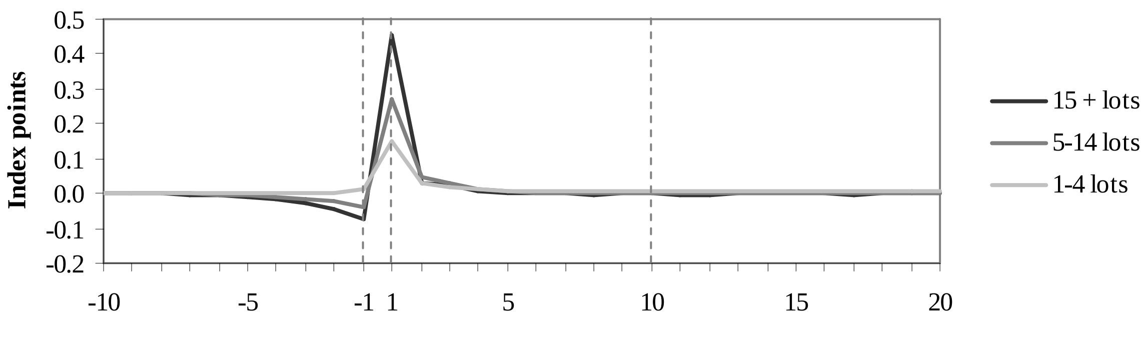
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



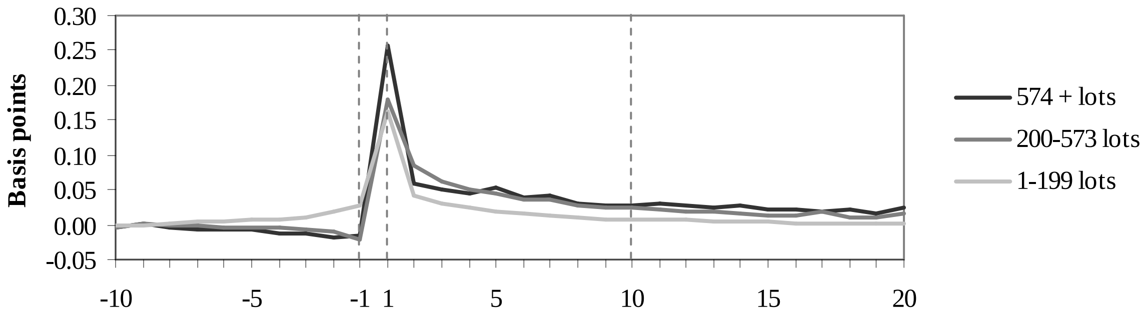
Panel D: SFE SPI 200™ futures



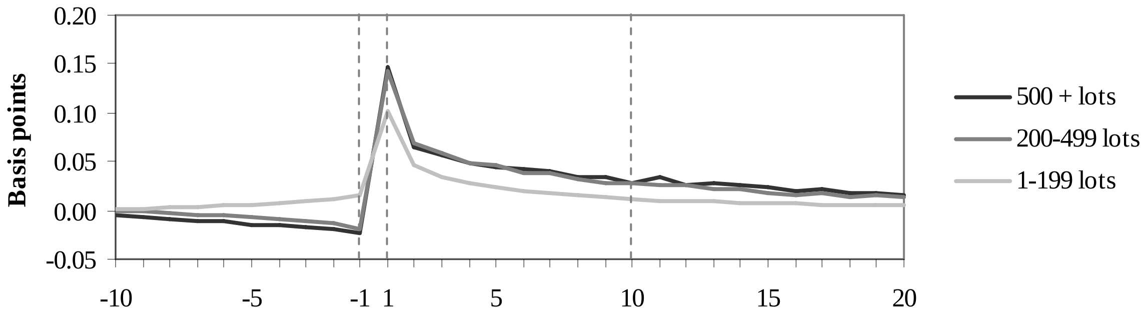
Excess volatility based on quotation prices by quote relative to the purchase of interest (trade 0) for small, medium and large purchases.

Figure A1.2
Excess quote volatility surrounding sales

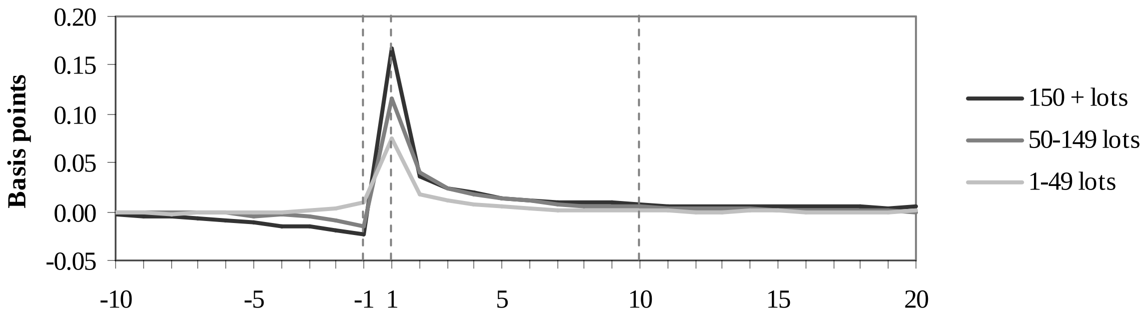
Panel A: 90 day bank bill futures



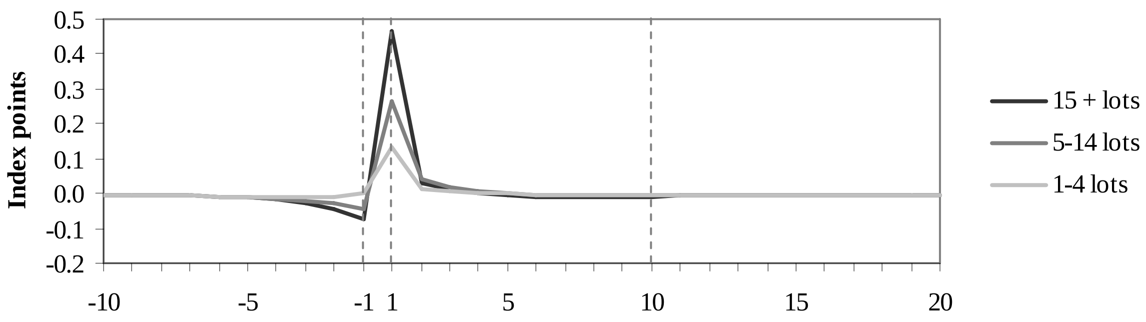
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



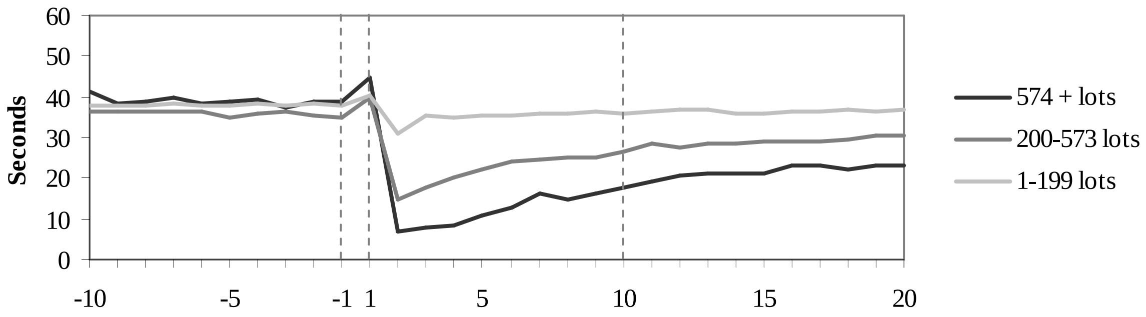
Panel D: SFE SPI 200™ futures



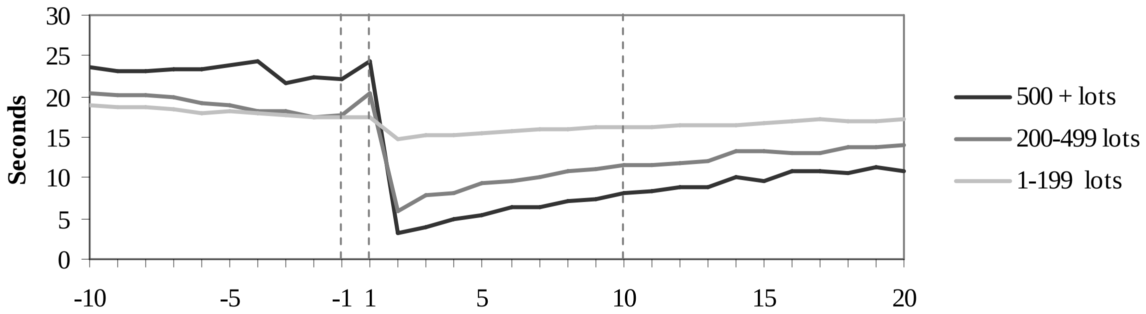
Excess volatility based on quotation prices by quote relative to the sale of interest (trade 0) for small, medium and large sales.

Figure A1.3
Time intervals between quotes surrounding purchases

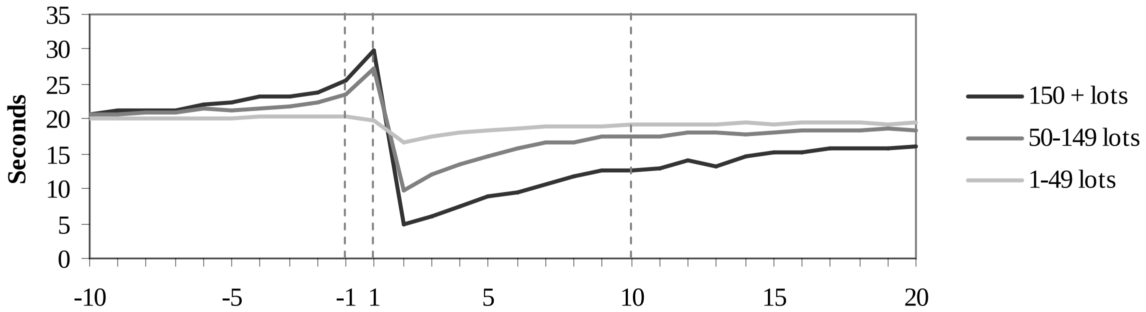
Panel A: 90 day bank bill futures



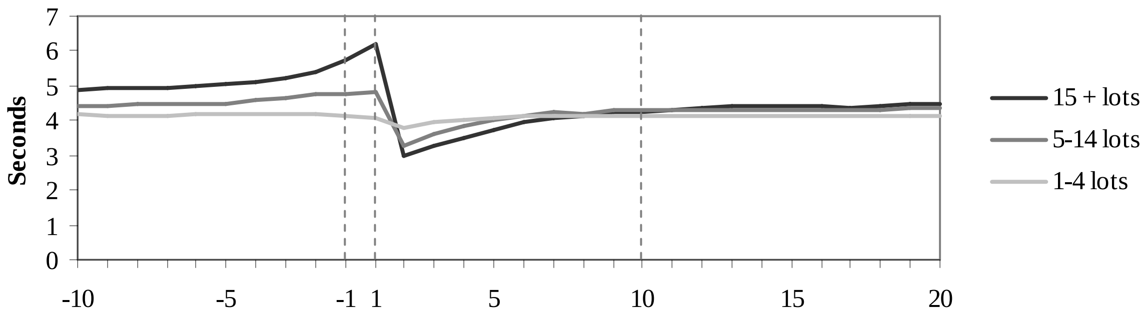
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



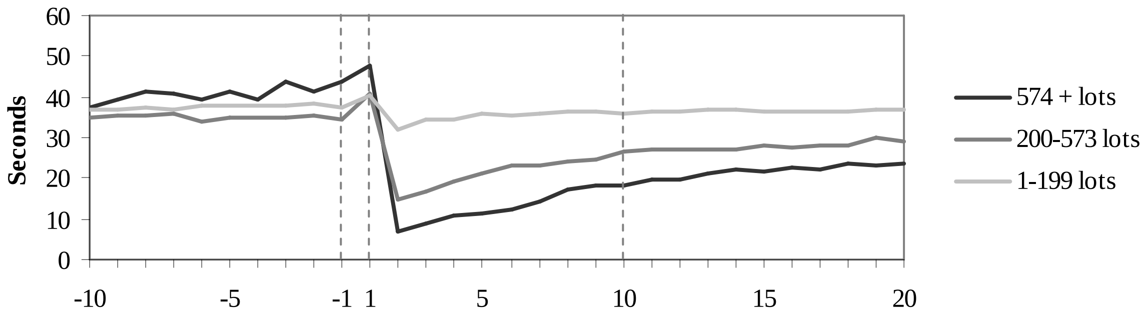
Panel D: SFE SPI 200™ futures



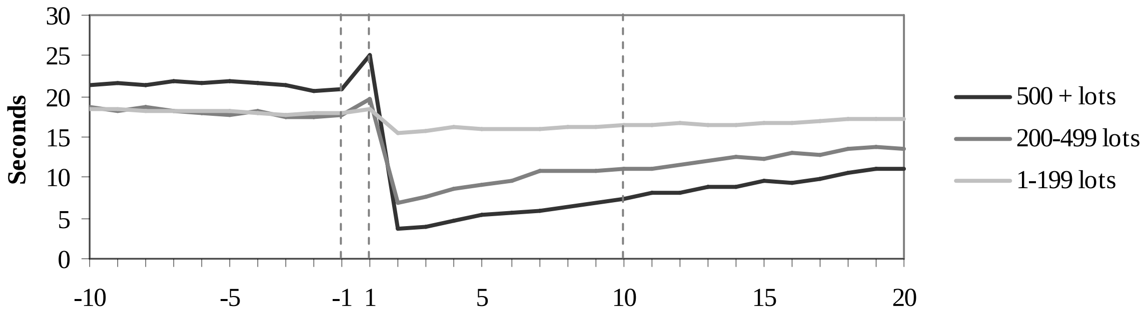
Time intervals between quotes relative to purchases of various sizes. Time intervals are in seconds. Trade 0 represents the block trade of interest.

Figure A1.4
Time intervals between quotes surrounding sales

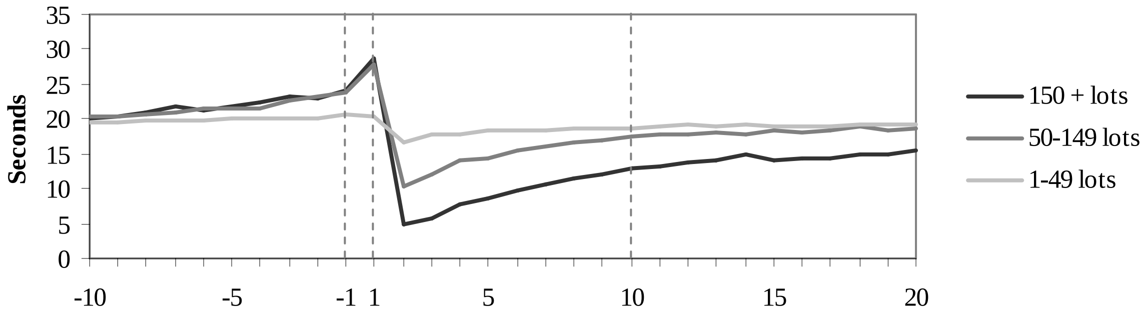
Panel A: 90 day bank bill futures



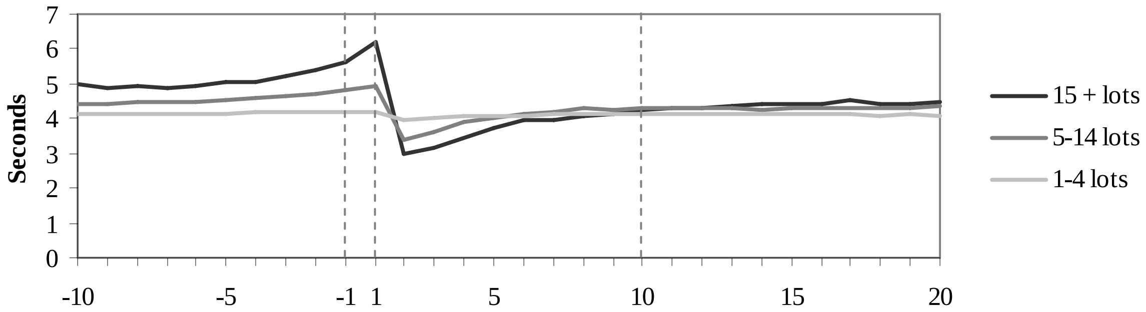
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



Panel D: SFE SPI 200™ futures



Time intervals between quotes relative to sales of various sizes. Time intervals are in seconds. Trade 0 represents the block trade of interest.

As expected, volatility is considerably higher for the outstanding quote after the block trade. Figure A1.1 shows that the mean absolute return after block purchases increases nine-fold from the benchmark period to 0.246 basis points for 90 day bank bill futures, five-fold to 0.140 basis points for 3 year Treasury bond futures, four-fold to 0.160 basis points for 10 year Treasury bond futures and two-fold to 0.456 index points for SFE SPI 200™ futures. The increased volatility persists for at least twenty quotes for 90 day bank bill futures and 3 year Treasury bond futures, eleven quotes for 10 year Treasury bond futures and four quotes for SFE SPI 200™ futures. The quote-to-quote absolute return prior to block purchases displays lower than normal volatility for four quotes for 90 day bank bill futures, at least ten quotes for 3 year Treasury bond futures and 10 year Treasury bond futures and seven quotes for SFE SPI 200™ futures. Similar results hold before and after block sales (figure A1.2). In summary, the evidence on the mean quote-to-quote absolute returns suggests that volatility decreases before the block trade, increases sharply at the block and persists at higher than benchmark levels for several subsequent quotes.

The time intervals between quotes surrounding small, medium and large trades for the main sample are shown in figures A1.3 and A1.4. There is evidence that large block trades are associated with a significant reduction in the time between quotes following block purchases for at least twenty quotes for the interest rate contracts and six quotes for the equity index contract (at the one percent level). The time between quotes is significantly longer up to the block purchase and before the block for at least ten quotes for 3 year Treasury bond futures and SFE SPI 200™ futures and seven quotes for 10 year Treasury bond futures, at the one percent level relative to the small-trade sample. The results for block purchases and block sales provide similar evidence. These findings suggest there is a lull in the placement of limit orders at or better than the best prevailing quotes prior to blocks, followed by a flurry of limit orders after blocks. This behaviour is consistent with Biais, Hillion and Spatt (1995), who find investors place limit orders relatively quickly when the liquidity has diminished for equities traded on the Paris Bourse.

Appendix 2

Trading direction, size and frequency

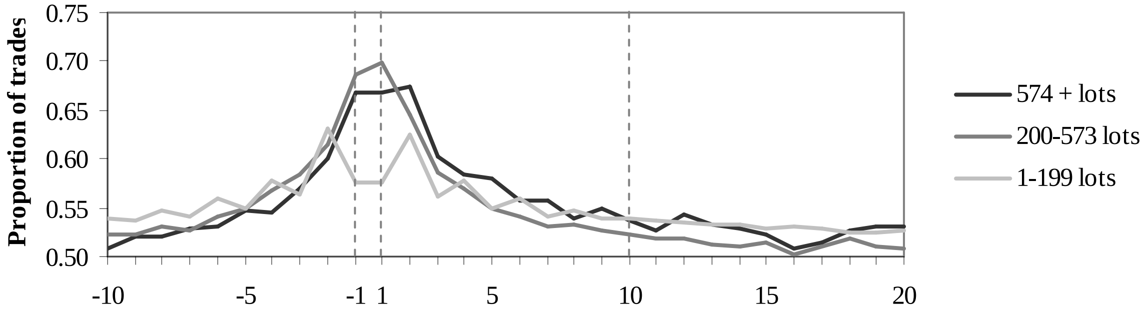
This appendix describes some additional characteristics of the sub-sample of trades identified in section 2.2.[31] Figures A2.1 to A2.6 illustrate changes in the direction of trade initiation, trade size and time between trades around purchases and sales of different sizes. Table A2.1 reports the average trade sizes and excess trade sizes around purchases and sales.

Figures A2.1 and A2.2 indicate that purchases are likely to be clustered with other purchases and sales are likely to be clustered with other sales respectively. For consecutive trades prior to block purchases, the proportion of trades classified as purchases is significantly greater than fifty percent (at the one percent level) for seven trades in 90 day bank bill futures, at least ten trades in 3 year Treasury bond futures and SFE SPI 200™ futures and three trades in 10 year Treasury bond futures. After block purchases, the proportion classified as purchases is significantly greater than fifty percent for fourteen trades in 90 day bank bill futures, at least twenty trades in 3 year Treasury bond futures, eight trades in 10 year Treasury bond futures and at least nineteen trades (following trade +1) in SFE SPI 200™ futures. The evidence concerning trade size is mixed in this respect. Series of trades around block purchases are significantly more likely to be purchases than the corresponding trades around small purchases for one preceding and three subsequent trades in 90 day bank bill futures and one preceding and five subsequent trades in 3 year Treasury bond futures. However, the reverse holds for at least ten preceding trades in 10 year Treasury bond futures and at least ten preceding and two subsequent trades in SFE SPI 200™ futures. Similar results hold around purchases and sales.

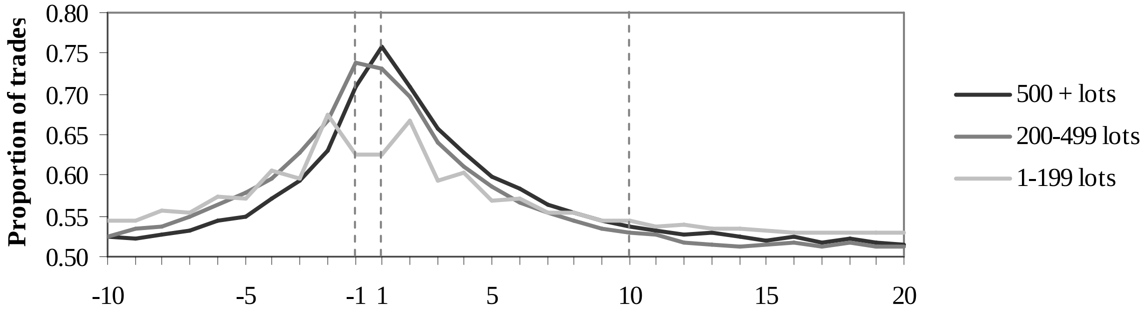
[31] Trades within the first 20 trades or the last 20 trades of the day are excluded from the analysis.

Figure A2.1
Purchases surrounding purchases

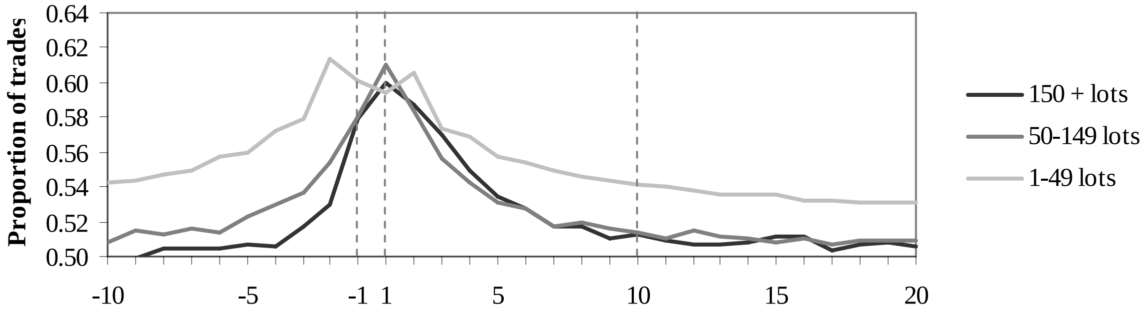
Panel A: 90 day bank bill futures



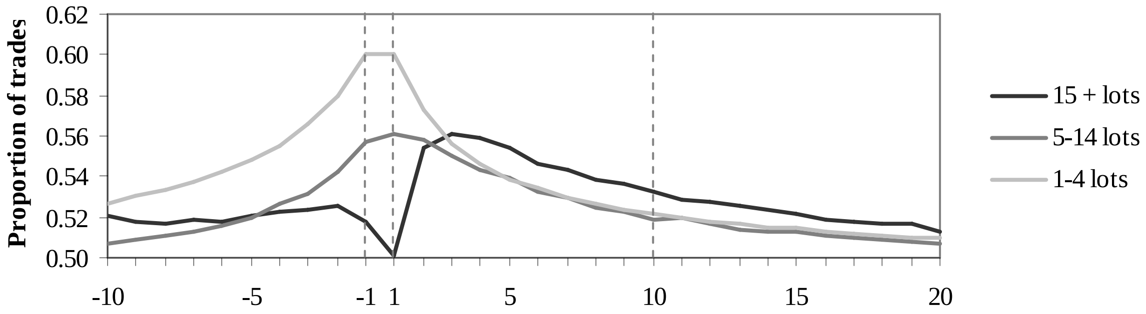
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



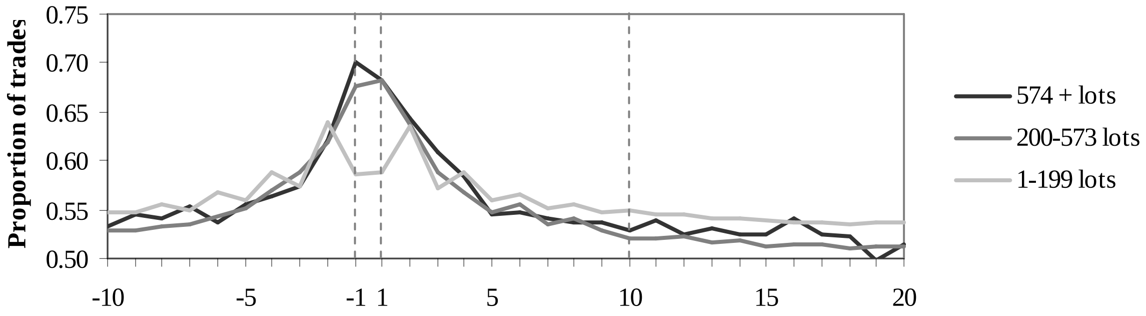
Panel D: SFE SPI 200[TM] futures



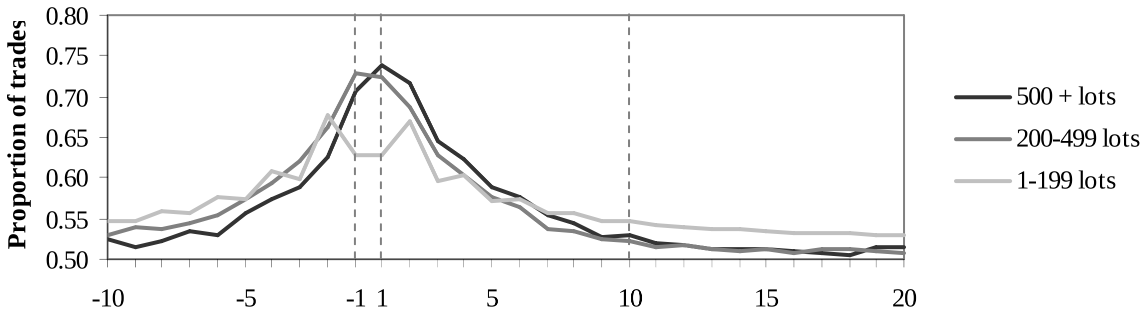
Proportions of trades classified as purchases relative to purchases of various sizes. All trades that occur above or equal to the prevailing ask price are classified as purchases and all trades that occur below or equal to the bid price are classified as sales. Trade 0 represents the block trade of interest.

Figure A2.2
Sales surrounding sales

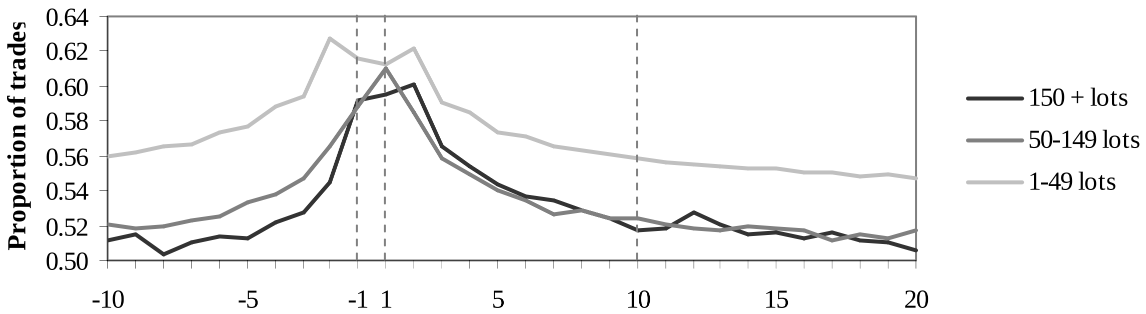
Panel A: 90 day bank bill futures



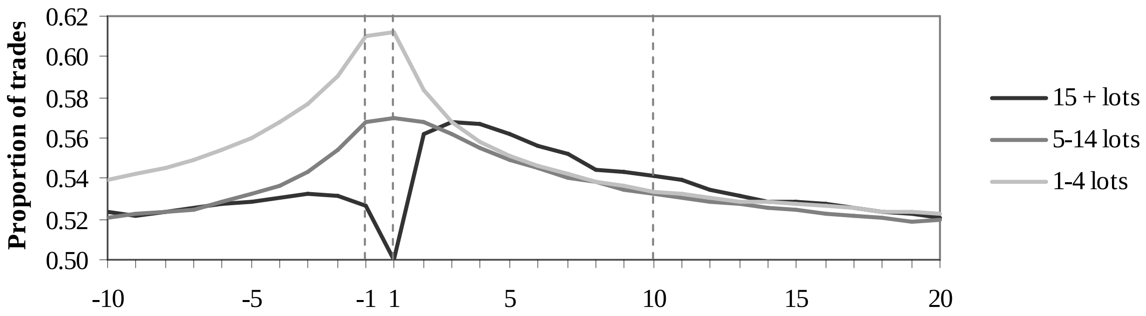
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



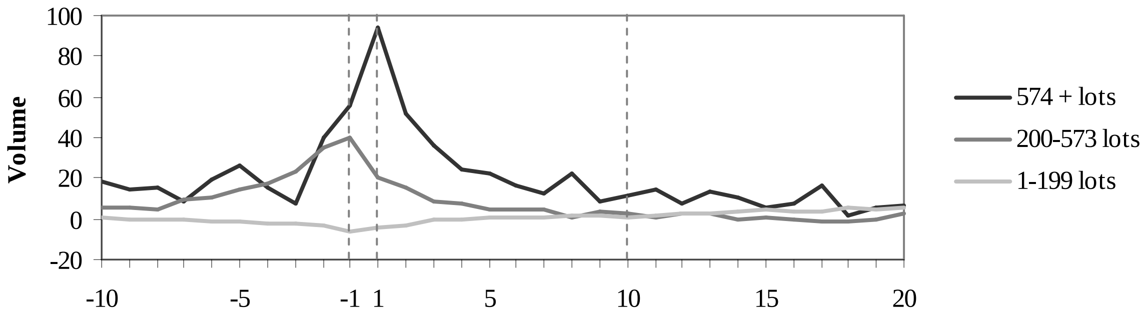
Panel D: SFE SPI 200™ futures



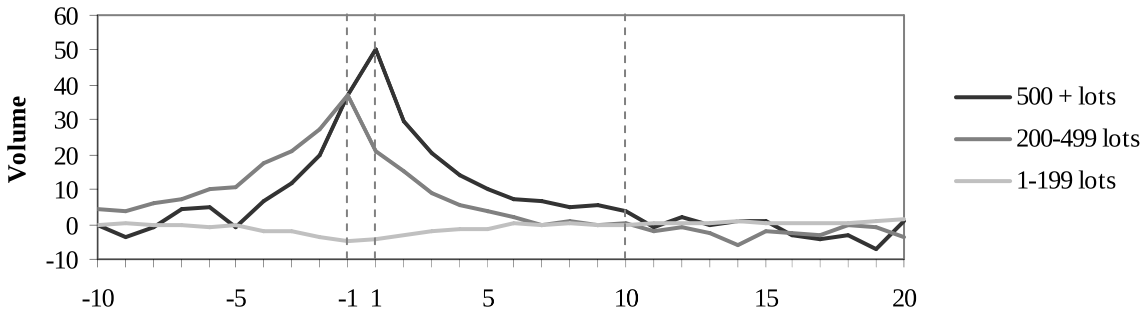
Proportions of trades classified as sales relative to sales of various sizes. All trades that occur above or equal to the prevailing ask price are classified as purchases and all trades that occur below or equal to the bid price are classified as sales. Trade 0 represents the block trade of interest.

Figure A2.3
Excess transaction sizes surrounding purchases

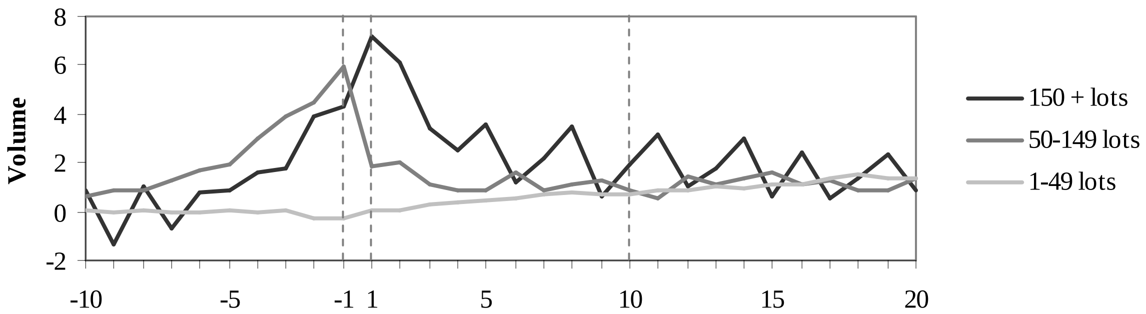
Panel A: 90 day bank bill futures



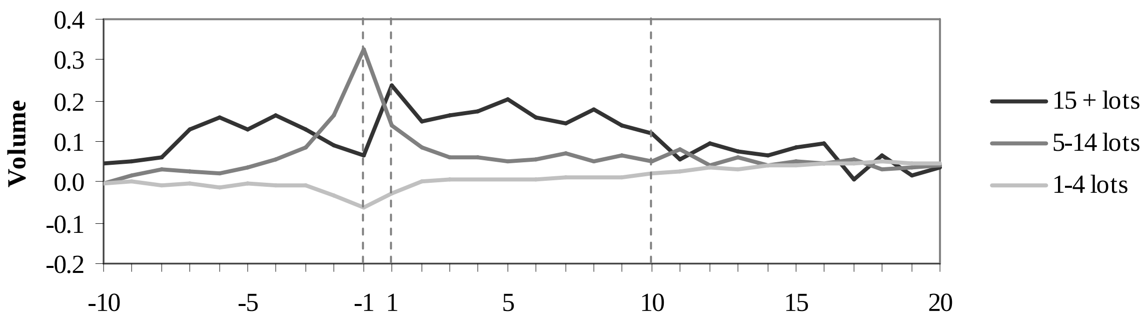
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



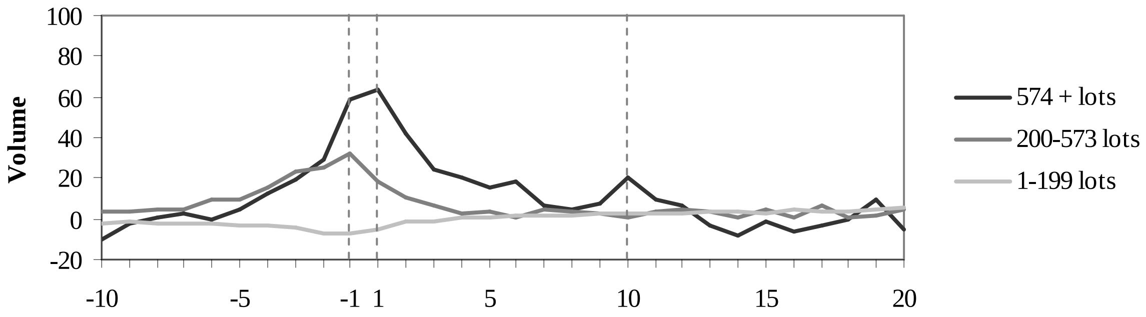
Panel D: SFE SPI 200™ futures



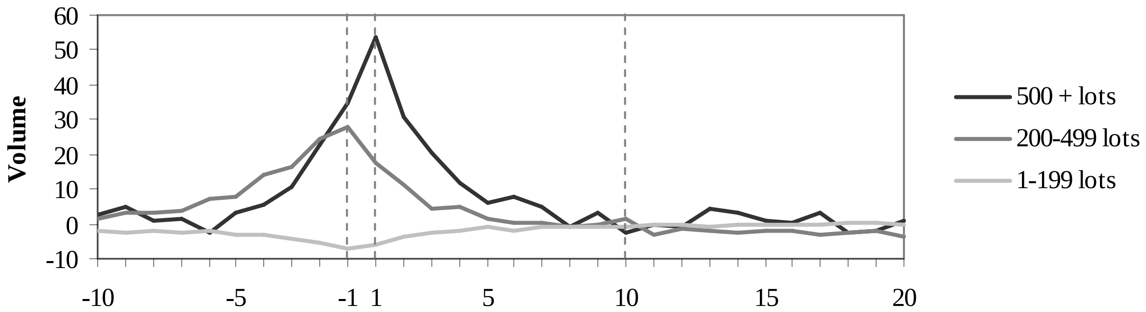
Excess transaction sizes relative to purchases of various sizes. Transaction size is in number of contracts. Trade 0 represents the block trade of interest.

Figure A2.4
Excess transaction sizes surrounding sales

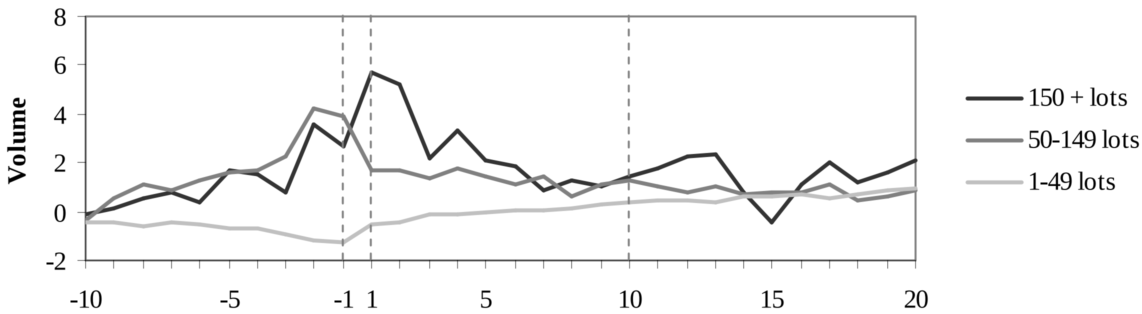
Panel A: 90 day bank bill futures



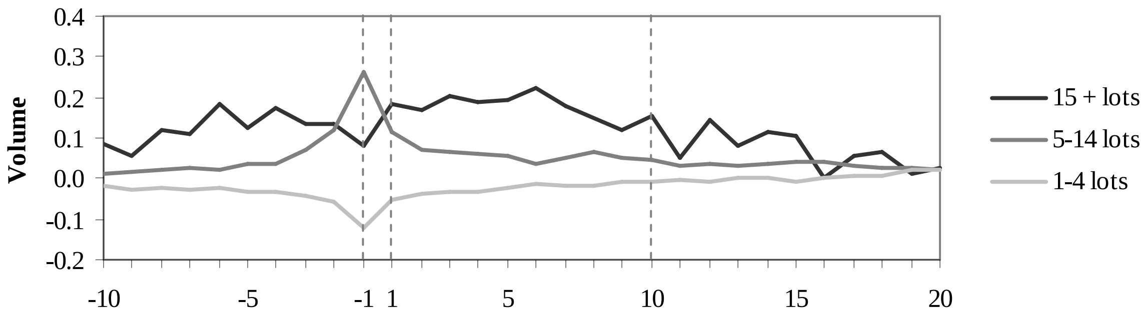
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



Panel D: SFE SPI 200™ futures



Excess transaction sizes relative to sales of various sizes. Transaction size is in number of contracts. Trade 0 represents the block trade of interest.

Table A2.1
Transaction sizes surrounding trades by direction and size of trade

	Trade relative to trade of interest (trade 0)									
	Purchases					**Sales**				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel A: 90 day bank bill futures										
1-199 lots										
Mean trade size	92.8	89.7	92.0	92.9	96.0	88.8	88.4	90.7	94.4	94.4
Mean excess trade size	-3.4	-6.5	-4.2	-3.3	-0.2	-6.8	-7.2	-4.9	-1.1	-1.1
t: Excess trade size = 0	-4.41	-8.75	-5.16	-4.06	-0.23	-9.05	-9.58	-6.24	-1.32	-1.40
200-573 lots										
Mean trade size	165.3	170.8	150.8	145.4	138.7	155.2	161.8	148.0	139.7	136.3
Mean excess trade size	35.0	40.5	20.5	15.1	8.4	25.5	32.2	18.4	10.0	6.6
t: Excess trade size = 0	11.67	13.60	8.34	6.18	3.21	8.96	10.85	7.76	4.20	2.77
574 + lots										
Mean trade size	195.5	211.9	249.4	207.8	191.6	187.2	216.1	221.7	199.9	182.1
Mean excess trade size	39.8	56.2	93.7	52.1	35.9	29.4	58.3	63.9	42.1	24.3
t: Excess trade size = 0	4.47	6.02	9.64	7.26	4.92	3.55	6.28	7.68	6.00	3.87
Panel B: 3 year treasury bond futures										
1-199 lots										
Mean trade size	83.6	82.6	83.1	84.4	85.3	81.8	80.0	81.0	83.2	84.6
Mean excess trade size	-3.6	-4.7	-4.2	-2.9	-2.0	-5.2	-6.9	-5.9	-3.8	-2.3
t: Excess trade size = 0	-8.65	-11.26	-9.49	-6.60	-4.45	-12.48	-16.98	-13.89	-8.69	-5.30
200-499 lots										
Mean trade size	132.6	142.4	126.1	120.8	114.2	129.3	132.6	122.3	115.7	109.0
Mean excess trade size	27.3	37.1	20.7	15.5	8.9	24.6	27.8	17.6	11.0	4.3
t: Excess trade size = 0	15.29	20.46	14.10	10.65	6.03	14.19	16.46	11.88	7.70	3.00
500 + lots										
Mean trade size	138.8	156.0	169.5	148.6	139.7	141.5	153.7	172.4	150.0	139.3
Mean excess trade size	19.8	36.9	50.5	29.5	20.7	22.5	34.7	53.5	31.0	20.3
t: Excess trade size = 0	6.69	10.84	16.73	11.45	7.94	6.75	10.00	16.68	11.22	7.63

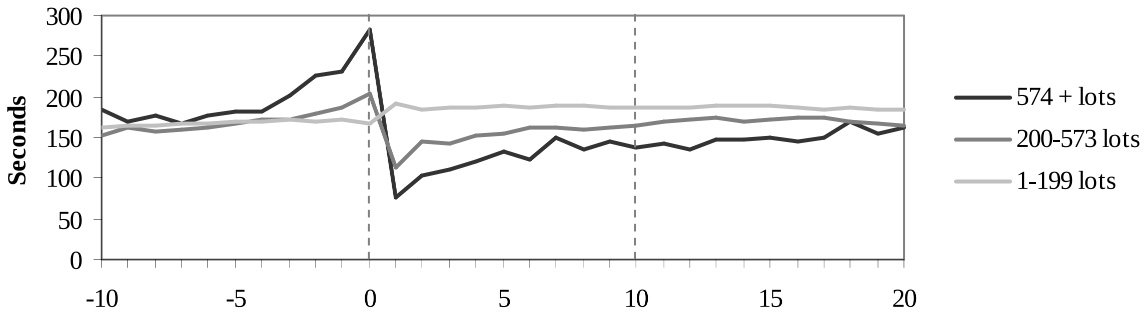
Table A2.1 *continued*

	Trade relative to trade of interest (trade 0)									
	Purchases					Sales				
Size of trade	**-2**	**-1**	**1**	**2**	**3**	**-2**	**-1**	**1**	**2**	**3**
Panel C: 10 year treasury bond futures										
1-49 lots										
Mean trade size	26.2	26.2	26.5	26.4	26.7	25.4	25.3	26.0	26.2	26.5
Mean excess trade size	-0.3	-0.3	0.1	0.0	0.3	-1.2	-1.2	-0.6	-0.4	-0.1
t: Excess trade size = 0	-2.47	-2.54	0.50	0.11	2.70	-11.66	-12.46	-5.24	-3.91	-0.92
50-149 lots										
Mean trade size	40.3	41.8	37.6	37.8	36.9	39.7	39.4	37.2	37.2	36.8
Mean excess trade size	4.4	5.9	1.8	2.0	1.1	4.2	3.9	1.7	1.7	1.3
t: Excess trade size = 0	13.24	17.04	6.13	6.53	3.64	12.72	11.78	5.72	5.62	4.39
150 + lots										
Mean trade size	49.8	50.2	53.0	52.0	49.3	50.1	49.2	52.2	51.7	48.7
Mean excess trade size	3.9	4.3	7.2	6.1	3.4	3.6	2.7	5.7	5.3	2.2
t: Excess trade size = 0	4.65	4.94	9.07	7.60	4.49	4.09	3.01	7.30	6.39	2.73
Panel D: SFE SPI 200™ futures										
1-4 lots										
Mean trade size	4.2	4.1	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.2
Mean excess trade size	0.0	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0
t: Excess trade size = 0	-5.48	-10.50	-4.53	0.28	0.82	-9.56	-20.97	-9.31	-6.54	-5.69
5-14 lots										
Mean trade size	5.0	5.2	5.0	4.9	4.9	5.0	5.1	5.0	4.9	4.9
Mean excess trade size	0.2	0.3	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1
t: Excess trade size = 0	13.39	27.61	11.91	7.39	5.21	10.21	22.02	9.88	5.93	5.47
15 + lots										
Mean trade size	6.0	6.0	6.2	6.1	6.1	6.1	6.0	6.1	6.1	6.1
Mean excess trade size	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.2
t: Excess trade size = 0	3.06	1.99	7.81	4.94	5.34	4.17	2.54	6.16	5.81	6.88

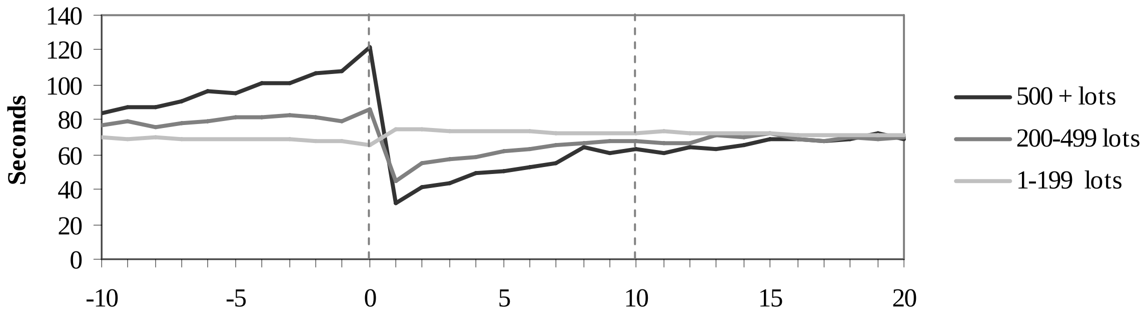
Summary statistics regarding trade sizes for trades relative to small, medium and large trades. *Mean trade size* is the mean trade size in number of contracts. Excess trade size is trade size in excess of a benchmark level, computed using trade sizes for trades -20 through -11 relative to trades of a given size. For excess trade size, reported results include *Mean excess trade size* and *t: Excess trade size = 0* (the *t*-statistic for the test of the null hypothesis that the mean excess trade size equals zero). Results are reported for 90 day bank bill futures (panel A), 3 year treasury bond futures (panel B), 10 year treasury bond futures (panel C) and SFE SPI 200™ futures (panel D).

Figure A2.5
Time intervals between trades surrounding purchases

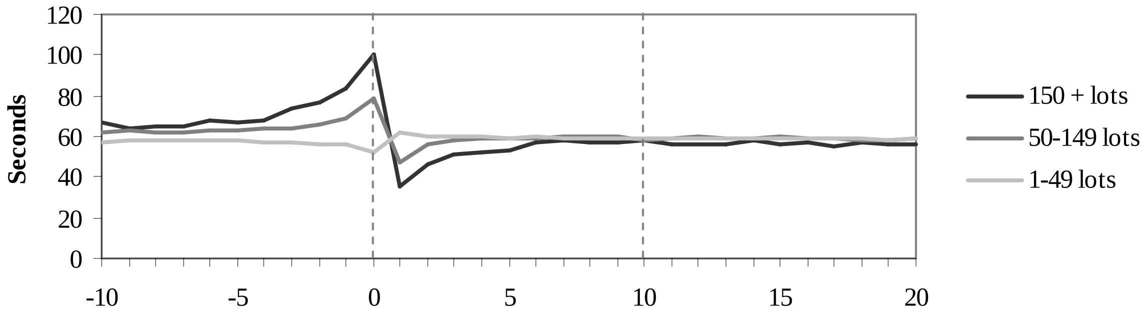
Panel A: 90 day bank bill futures



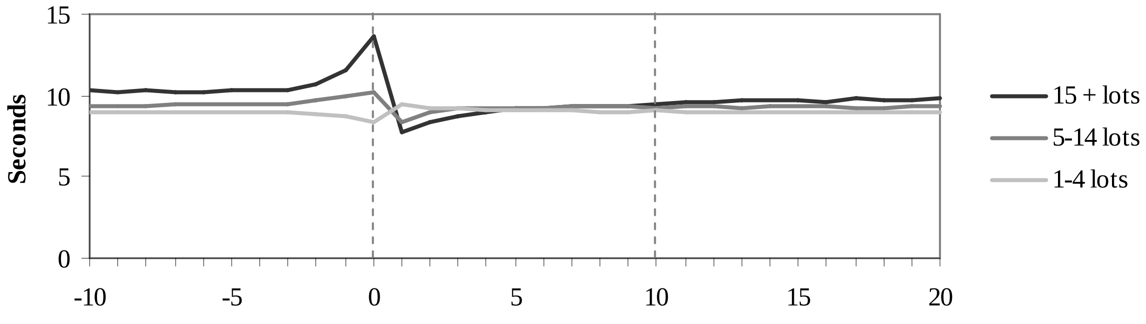
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



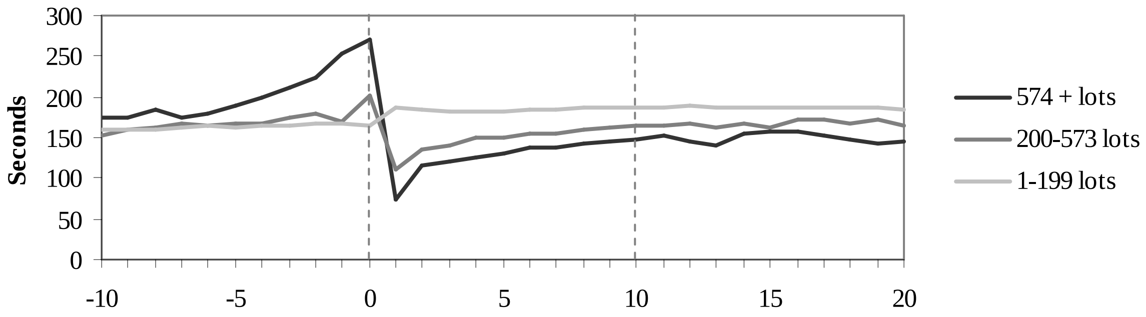
Panel D: SFE SPI 200™ futures



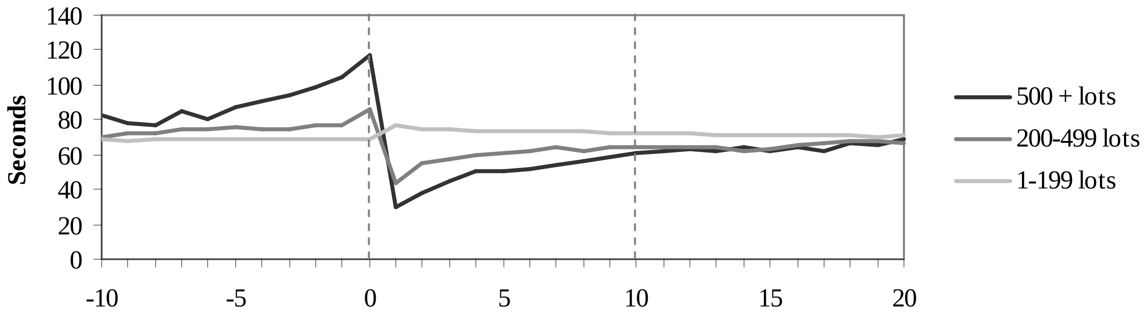
Time intervals between trades relative to purchases of various sizes. Time intervals are in seconds. Trade 0 represents the block trade of interest.

Figure A2.6
Time intervals between trades surrounding sales

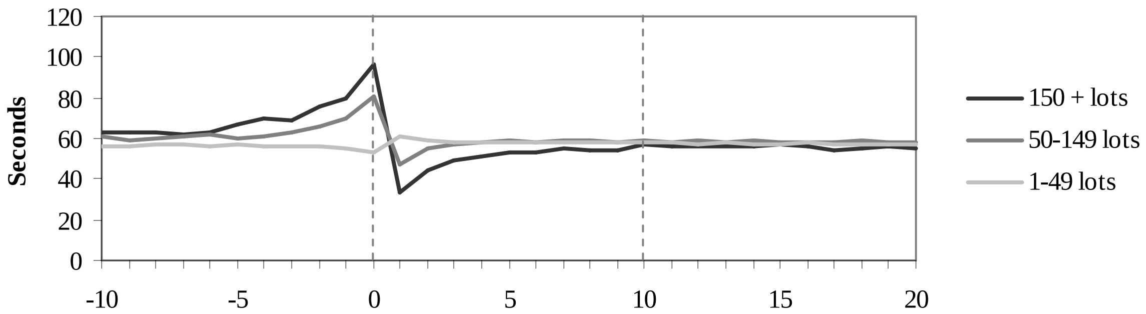
Panel A: 90 day bank bill futures



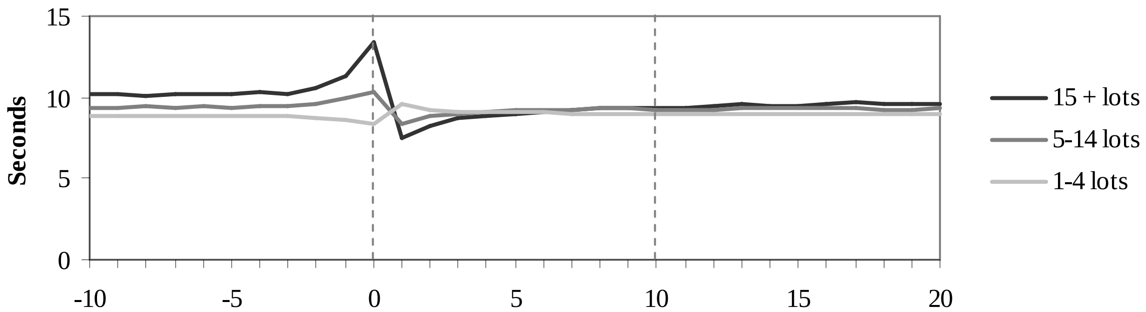
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



Panel D: SFE SPI 200™ futures



Time intervals between trades relative to sales of various sizes. Time intervals are in seconds. Trade 0 represents the block trade of interest.

To measure trading activity, mean trade sizes relative to purchases of size *z* are computed as

$$\overline{T}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)} T_{i,j,t}(z)}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \tag{A2.1}$$

where $T_{i,j,t}(z) \equiv$ trade size (expressed in number of contracts) for contract maturity *i* at quote *t* relative to the trade of interest *j* of size *z*. A benchmark trade size series for each maturity is constructed using the size of trades -20 through -11 relative to all trades of size *z*. Mean excess trade sizes relative to purchases are computed as

$$\overline{RT}_t(z) = \frac{\sum_{i=1}^{28}\sum_{j=1}^{N_{i,pur}(z)} [T_{i,j,t}(z) - BENSIZ_i(z)]}{\sum_{i=1}^{28} N_{i,pur}(z)} \quad t = -10, \ldots, +20 \tag{A2.2}$$

where

$$BENSIZ_i(z) = \frac{\sum_{j=1}^{N_{i,pur}(z)+N_{i,sal}(z)} \sum_{t=-20}^{-11} T_{i,j,t}(z)}{N_i(z)} \quad i = 1, \ldots, 28$$

This methodology is used to compute benchmark and excess trade size statistics relative to small, medium and large purchases and sales.

Figures A2.3 and A2.4 show that large trades are associated with an increase in trading activity as measured by trade size (see also table A2.1). For example, the average trade size increases from 211.9 lots immediately preceding large block purchases to 249.4 lots immediately following block purchases of 90 day bank bill futures (this change is statistically significant). Trade sizes after block purchases remain significantly above those in the benchmark period for six trades in 90 day bank bill futures and 3 year Treasury bond futures, five trades in 10 year Treasury bond futures and ten trades in SFE SPI 200^{TM} futures. Results also indicate that trade sizes prior to block purchases are significantly above normal levels for two trades in 90 day bank bill futures and 10 year Treasury bond futures, three trades in 3 year Treasury bond futures and six trades (preceding trade -1) in SFE SPI 200^{TM} futures. Similar results hold for purchases and sales.

The clustering of trades initiated in the same direction and increased trading activity around large trades provide support for Easley and O'Hara's (1987) prediction that the entire sequence of trades, not merely the aggregate volume, determines the price effects of large trades. An important characteristic of their information-effects model is that the entire sequence of past trades is informative about the likelihood of an information event.[32] The empirical results in this appendix suggest that the price and liquidity effects of large futures trades are not produced by large trades in isolation; they occur as a result of the order placement strategies and trading activity accompanying large trades. In comparison, Holthausen, Leftwich and Mayers (1990) find evidence that large up-tick transactions in NYSE-listed equities occur during times of increased trading activity as measured by the average trade size and time between trades, whereas for downticks the trades are not systematically different in size and frequency from those in their benchmark period.

Figures A2.5 and A2.6 suggest that block futures trades stimulate subsequent trading activity. The time between trades following both block purchases and block sales is significantly shorter than after small trades for seventeen trades in 90 day bank bill futures, fourteen trades in 3 year Treasury bond futures, five trades in 10 year Treasury bond futures and three trades in SFE SPI 200™ futures. The mean time between trades is significantly greater up to the block itself and before the block for three trades in 90 day bank bill futures and at least ten trades in the other contracts, relative to the small-trade sub-sample. These findings suggest that trading activity is relatively sluggish prior to blocks, followed by a burst of activity commencing immediately after blocks.

The surge in trading activity prompted by blocks is consistent with Easley and O'Hara's (1992b) analysis of the effects of information event uncertainty on market behaviour. They demonstrate that a trade at time t increases the likelihood that an information event has occurred and this, in turn, increases the likelihood of a trade at time $t + 1$. This follows because when any kind of information event occurs, trades are more likely to occur and volume will be high because the informed always trade on the strength of their differential interpretation of the event. The surge in trading volume implied by the substantially reduced

[32] Therefore, Hasbrouck (1991) emphasises that the information content of a trade can only be meaningfully measured as the persistent price impact of the unexpected component of the trade (which he refers to as the 'trade innovation'). Serial dependencies in quote revisions and trades imply that some portion of the information content of large trades is expected, with the remainder representing the trade innovation. As predicted by Hasbrouck, the price impact of trades reported in section 3 is not felt instantaneously but with a protracted lag over several quote revisions.

time between trades observed after blocks also resembles the surge in trading volume reported by Fleming and Remolona (1999) from the United States Treasury market in the second stage of the market adjustment to the information contained in scheduled macroeconomic announcements. Without the same dramatic widening in bid-ask spreads in the minute of the announcement seen for the United States five-year Treasury note (nearly six times its average on non-announcement days), the surge in trading volume begins sooner following block trades in futures markets.