Price formation and liquidity surrounding large trades in interest rate and equity index futures: Further evidence from the Sydney Futures Exchange

James Richard Cummings
University of Sydney

Alex Frino
University of Sydney

Abstract

This paper examines the effects of contract-specific attributes, 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 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 primarily an 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 trades 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. 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. Hence, an investigation is warranted of the impact of asymmetric information as measured by trade size in financial futures markets. Further, research on how order-driven financial markets provide liquidity when large trades arrive is often confined to bid-ask spreads, 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 diminishes 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. The 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.

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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. The temporary price effects of large trades observed in equity markets have been explained in terms of liquidity costs (including adverse selection, inventory control and search components), whereas permanent price effects are often ascribed to either inelastic demand conditions or information[1]. 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 some evidence of a permanent price impact for futures trades. However, their results reveal that much of the initial price reaction is reversed and the permanent price effect is small. Our study validates whether the precipitous 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, the search for evidence that large trades contribute to the information dissemination process is extended to a broader range of financial futures contracts.

The speed of price adjustment is gauged to determine whether incentives exist for liquidity providers to restrict the size of sequential price changes in futures markets. Dann, Mayer and Raab (1977) present early evidence on the speed of adjustment of stock prices to large block transactions on the New York Stock Exchange (NYSE); although the adjustment is rapid, the prices do not appear to be unbiased estimates of closing prices until more ten minutes after the occurrence of the block. 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 rationale) or to incentives for 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 the speed of response to seller-initiated transactions depends on block size: the larger the block, the slower the adjustment. 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. The price adjustment to large futures trades is observed to determine whether there is any support for the compensation rationale, the orderly market hypothesis or the 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 examined by focussing on systematic changes to quoted liquidity surrounding large-trade execution, as well as the time taken for liquidity to return to normal levels. 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

[1] 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. 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) and Aitken and Frino (1996) in Australia provide empirical evidence of the price effects of large trades in equity markets.

Bernstein, 1987). Evidence presented by Moulton indicates quoted 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)[2]. He also finds that the return of liquidity to base levels is significantly related to the use of quoted liquidity in filling 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 substantiate that 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 previous levels, is adopted as a guide to the resiliency of interest rate and equity index futures markets to the impact of large trades. Thus, a more complete picture of market resiliency is obtained than provided by the recovery times for bid-ask spreads alone.

The liquidity supply response to large futures trades is analysed, to determine whether liquidity providers make the same strategic choices to those they adopt in equity markets. Specialists and other liquidity providers in equity markets actively manage adverse selection risk by adjusting both spreads and depths[3]. Koski and Michaely (2000) show that spreads increase significantly and depths decrease significantly after large trades on the NYSE, though not after small trades[4]. The findings of other studies are consistent with an increase in information asymmetry after large trades[5]. 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 the bid-ask spread is 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[6]. Limit order traders monitor the order book and wait for favourable order placement opportunities. It is sought to ascertain how quickly these opportunities re-emerge as the adverse selection problem is brought under control following large market orders in futures markets.

This paper tests the predictions of information models that incorporate quoted depth. Recognising that market makers' size quotes have received scant research attention

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[2] 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).
[3] Kavajecz (1999) demonstrates that depths are used as a strategic choice variable by NYSE specialists, with changes in quoted depth consistent with specialists managing their inventory positions as well as having knowledge of the future value of the stock.
[4] Furthermore, Koski and Michaely (2000) 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.
[5] For NYSE-listed equities, Lee, Mucklow and Ready (1993) show that liquidity drops 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.
[6] Similarly, Aitken, Frino and Sayers (1994) do not detect any significant disruption to spreads surrounding block trades in Australian equities.

relative to their price quotes, Mann and Ramanlal (1996) model the adverse selection component of the bid-ask spread and the corresponding component of the size quotes in a competitive dealership market. They find that the size quote 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[7]. Dealers lower size quotes as a first response to a decrease in market liquidity, and only when this is not possible do they resort to wider spreads. As well as being the first casualty of the disruption to market liquidity caused by a large trade, it is examined to what extent the size quotes are slower to recover than the spreads, consistent with Mann and Ramanlal's theoretical prediction.

With reference to the liquidity adjustment surrounding large trades, this paper demonstrates 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) 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 an 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)[8]. In making an investment decision based on public information, investors gain an advantage from superior information processing skills

[7] 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 quotes asymmetric.
[8] 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.

rather than from having seen the numbers first[9]. 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 delivered to futures markets through large trades, distinctly from information that is delivered through other forms of information media[10].

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). Not quite the same luxury of foresight is available for 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[11]. 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 (SFE) 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.

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[9] 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.

[10] 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.

[11] Not all studies are unequivocal about the rapid reaction of futures prices to macroeconomic announcements. For instance, 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.

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[12]. 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, 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 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.

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 single 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 is 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.

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[12] 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.

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 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). 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[13]. 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 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[14].

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[15]. Secondly, trades within the first 20 quote revisions or the last 20 quote revisions of the day are excluded to obtain continuous series that

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[13] 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.

[14] The Sydney Future Exchange (SFE) introduced an off-market block trade facility for SFE SPI 200™ Index 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 through the off-market facility, representing 1.2 percent of the total volume transacted in SFE SPI 200™ futures. Trades arranged through the off-market facility are excluded, given that different order arrangement and publication rules apply to these trades.

[15] 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.

demonstrate adjustments to the order book surrounding trades. The main sample resulting from the application of these two criteria is shown 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**

This main sample of trades was then ranked by size and divided into tritiles 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[16]. Table 1 provides descriptive statistics on the characteristics of the sample trades in the four contracts. There are 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. It does not appear that trading activity is concentrated in one direction (purchases or sales) in such a way as to bias the results. 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.

[16] 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, 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.

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[17].

The transparency of 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 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) show 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.

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

[17] 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.

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. 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

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

where

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

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[18]. 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

[18] 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.

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.

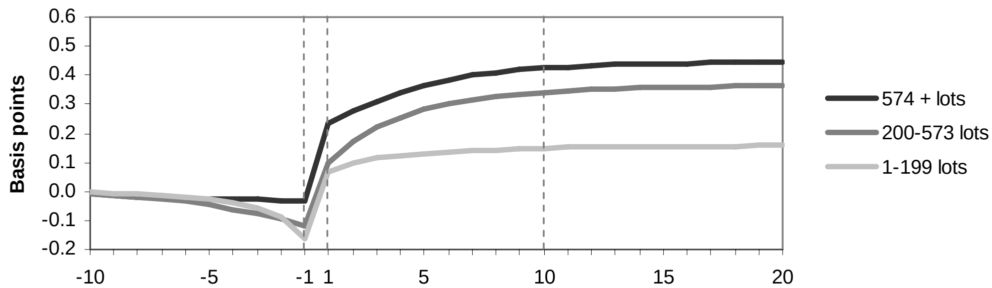
Traders exercise a degree of patience in executing small and medium trades that is not evident for block trades. Ask quotes decrease prior to the arrival of small and medium purchases and bid quotes increase prior to the arrival of small and medium sales. Small and medium trades take place when prices 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 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.

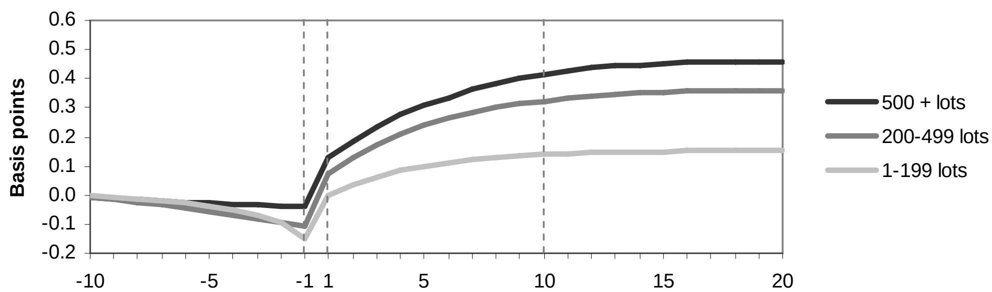
The price adjustment process is hastened by the speed of quote revisions after blocks. In quote update time, consecutive ask quote returns after block purchases are positive and significant across seven quotes for 90 day bank bill futures, twelve quotes for 3 year Treasury bond futures, eight quotes for 10 year Treasury bond futures and twelve quotes (following a slight recovery) for SFE SPI 200™ futures. In clock time, 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 hold after 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 the release.

Figure 1
Cumulative excess quote returns surrounding purchases

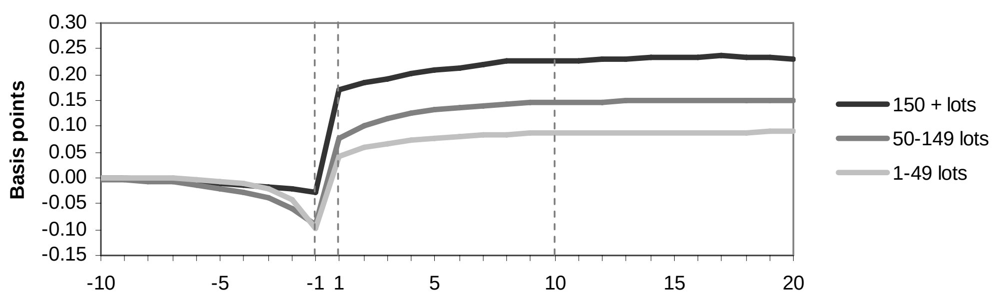
Panel A: 90 day bank bill futures



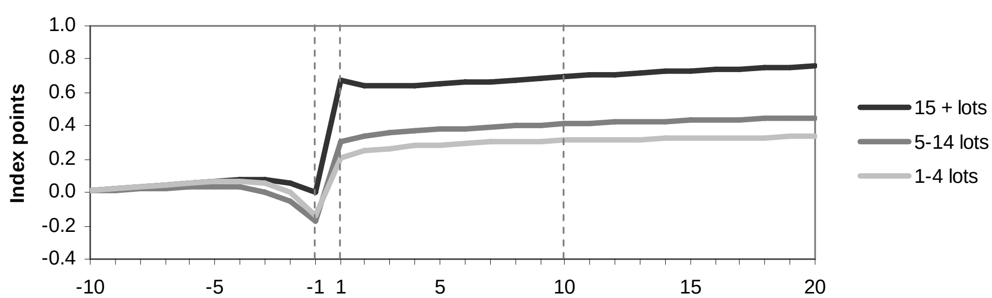
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



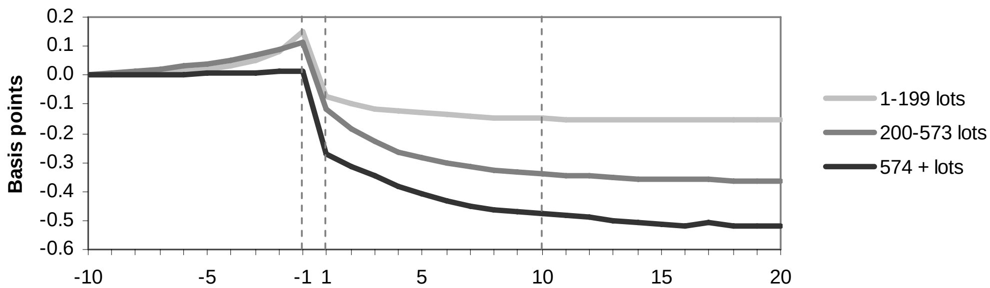
Panel D: SFE SPI 200™ futures



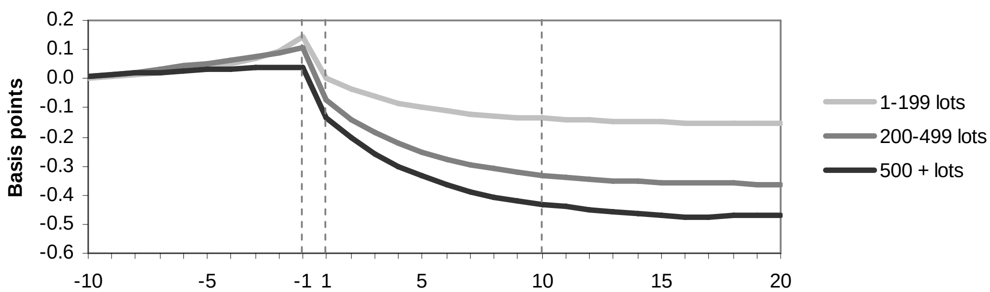
Cumulative excess returns based on quotation prices by quote relative to the purchase of interest (trade 0) for small, medium and large purchases.

Figure 2
Cumulative excess quote returns surrounding sales

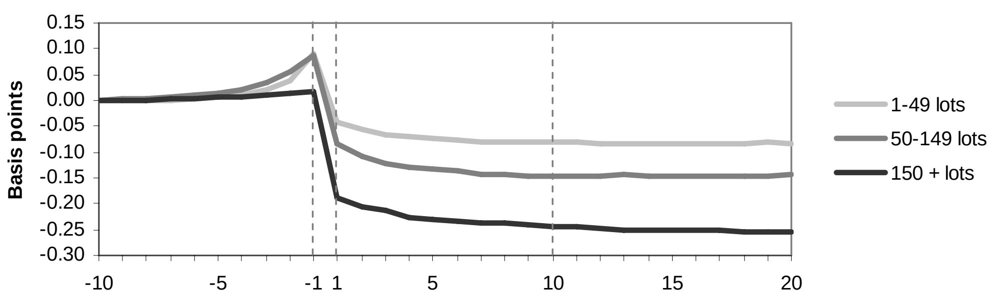
Panel A: 90 day bank bill futures



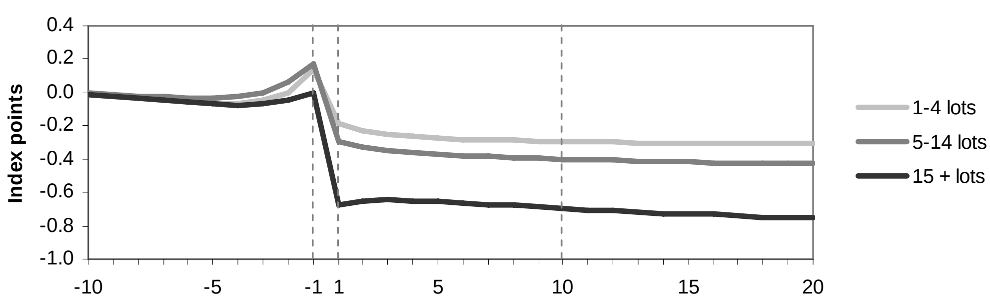
Panel B: 3 year Treasury bond futures



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
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™ 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™ 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. 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[19]. 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 on-market 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 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). 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

[19] 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.

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.

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 that 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[20].

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[21]. This finding is

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[20] 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.

[21] 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

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 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[22]. 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.

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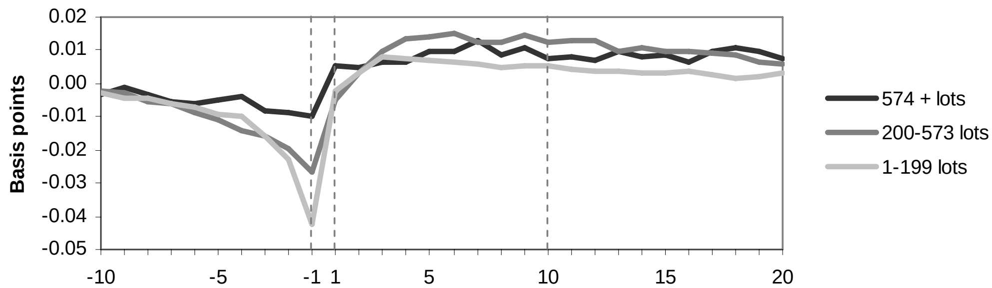
for SFE SPI 200™ futures. These depths and order sizes are positively correlated across the contracts, as predicted by Mann and Ramanlal's (1996) information model that incorporates quoted depth.

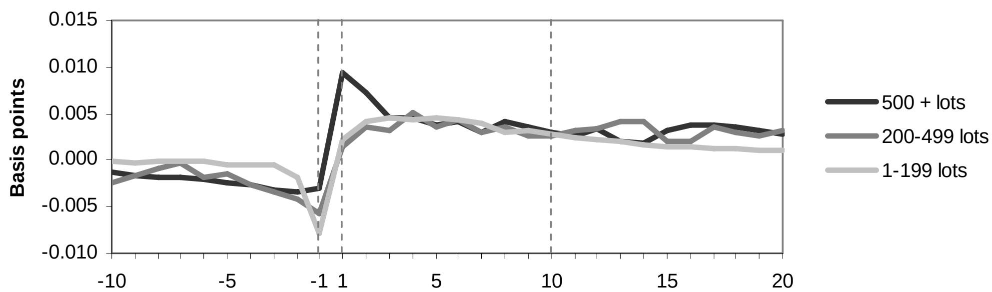
[22] Increases in depth immediately after small and medium trades reflects the fact that these trades clean out outstanding limit orders at the best prevailing quotes, revealing greater depth at higher ask prices for purchases and lower bid prices for sales.

Figure 3
Excess bid-ask spreads surrounding purchases

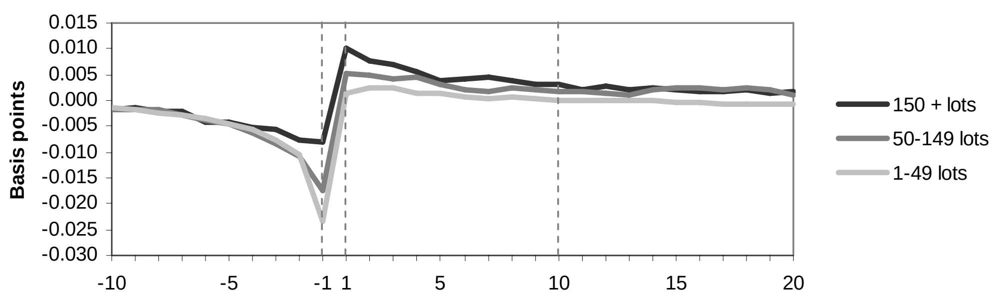
Panel A: 90 day bank bill futures



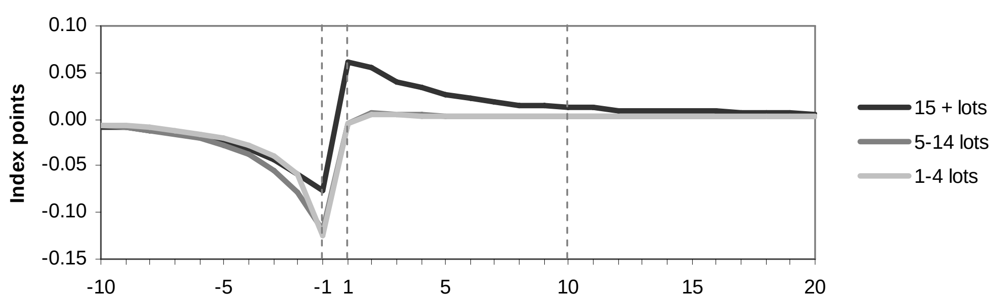
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



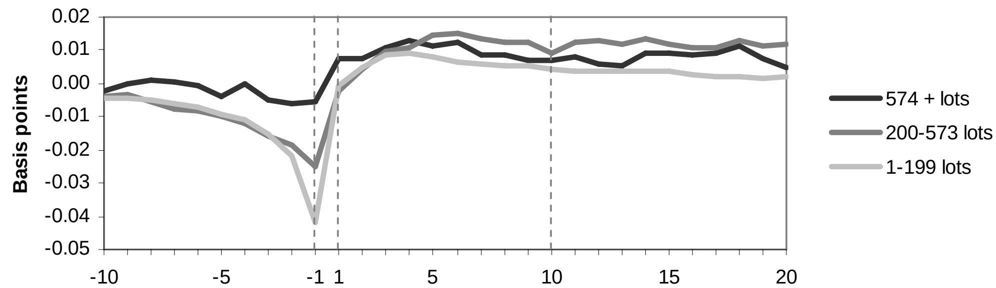
Panel D: SFE SPI 200™ futures



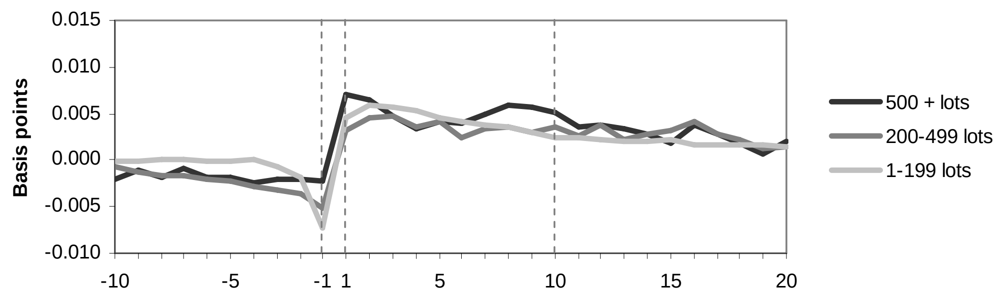
Excess bid-ask spreads relative to purchases of various sizes. Trade 0 represents the block trade of interest.

Figure 4
Excess bid-ask spreads surrounding sales

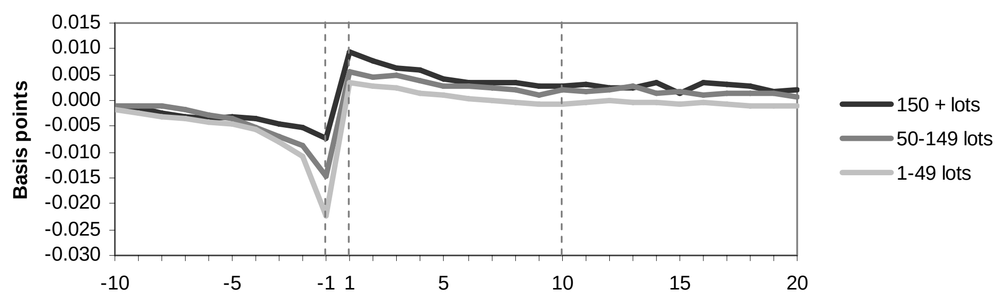
Panel A: 90 day bank bill futures



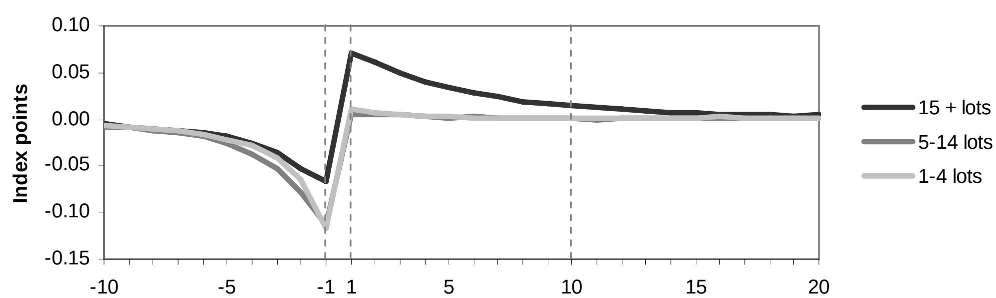
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



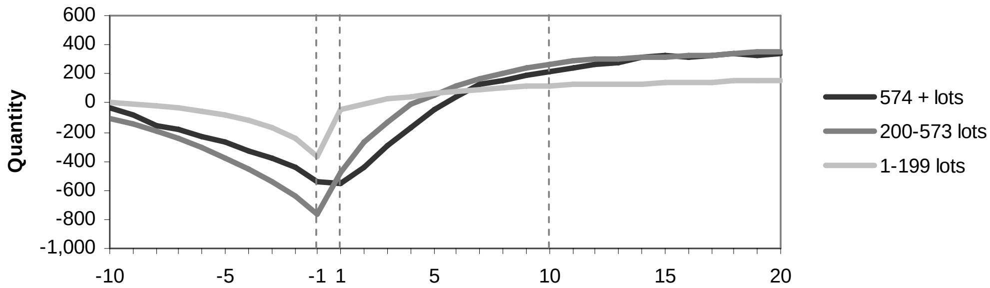
Panel D: SFE SPI 200™ futures



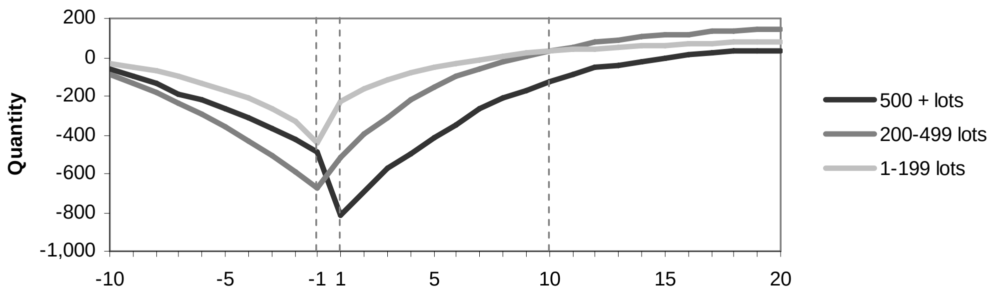
Excess bid-ask spreads relative to sales of various sizes. Trade 0 represents the block trade of interest.

Figure 5
Excess market depth surrounding purchases

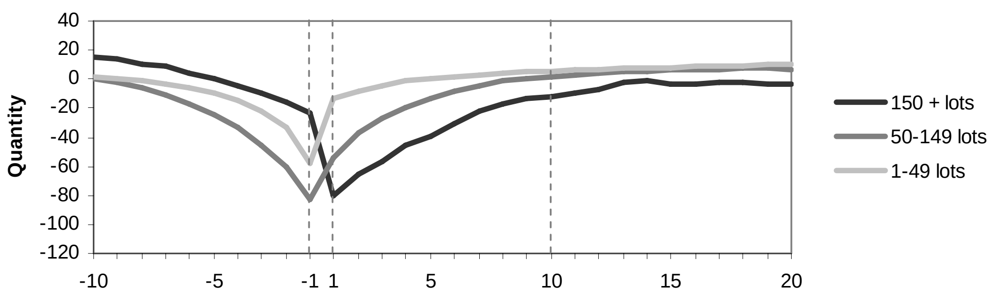
Panel A: 90 day bank bill futures



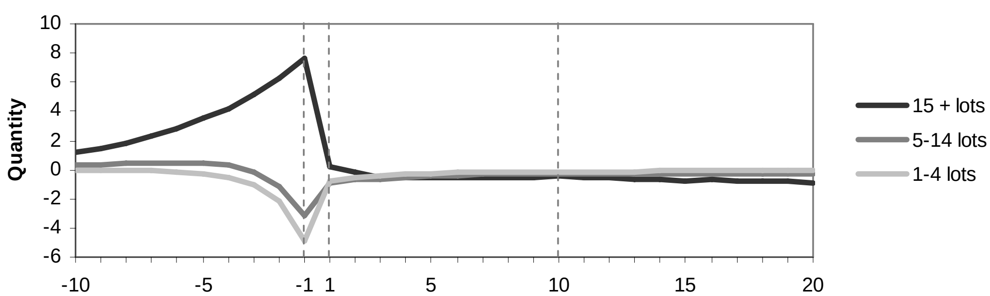
Panel B: 3 year Treasury bond futures



Panel C: 10 year Treasury bond futures



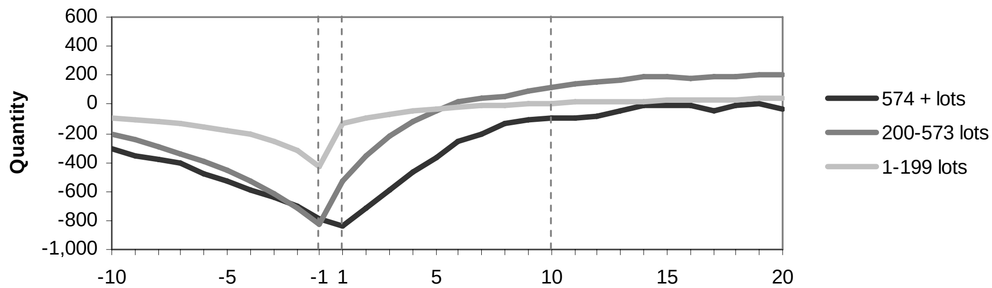
Panel D: SFE SPI 200™ futures



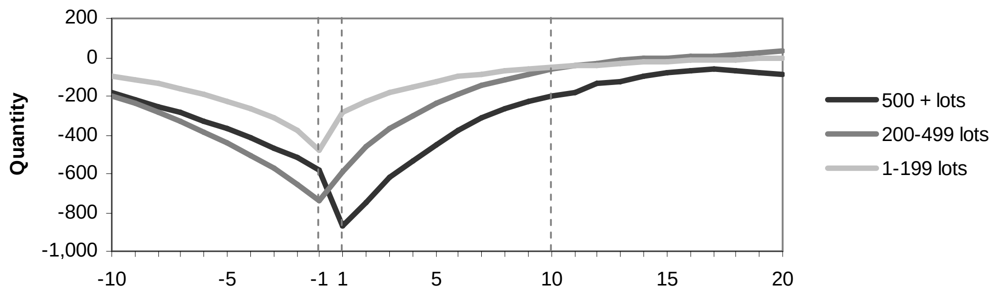
Excess market depth (ask quote depth) relative to purchases of various sizes. Depth is in number of contracts. Trade 0 represents the block trade of interest.

Figure 6
Excess market depth surrounding sales

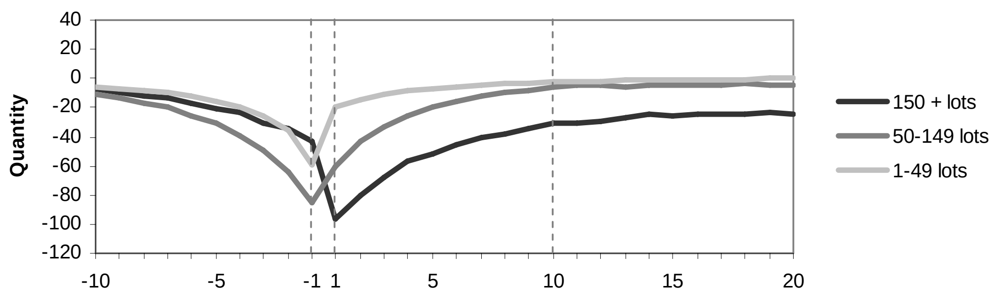
Panel A: 90 day bank bill futures



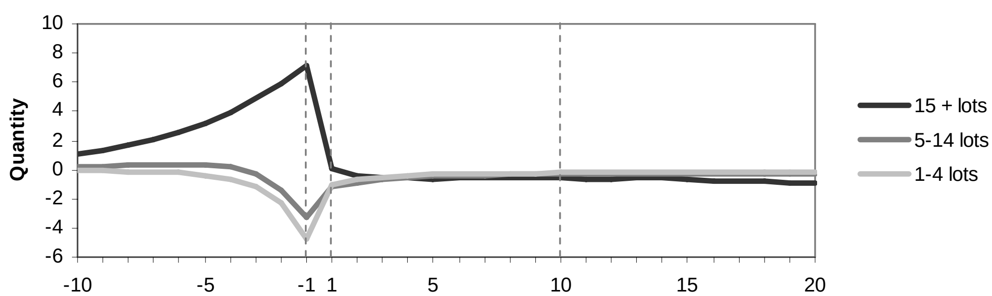
Panel B: 3 year Treasury bond futures



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
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™ 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™ 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
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™ 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™ futures (panel D).

In the same way 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 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[23]. 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 are sooner to begin recovering while depths remain slightly below normal levels.

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 primarily an 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

[23] 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).

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[24].

Diminished depths on the active side of the limit order book after block trades, met by consecutive trades in the same direction (not reported), 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[25]. 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.

5. Conclusion

Futures markets 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

[24] 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.

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

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 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 primarily an 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 (not reported); 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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