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Keywords

Minimum price variation, tick, depth, volatility, bid-ask spread, futures market

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ABSTRACT

This paper investigates the relationship between the minimum price variation and market quality variables for 3 interest rate futures contracts on the Sydney Futures Exchange. Intraday trade and quote data are obtained for the period 4 January 2000 and 1 February 2002, which includes the change in transparency on 19 January 2001. Analysis of the frequency distributions of bid and ask quote variations show a high frequency of these variations posted at 1 tick in the sample periods. Analysis of the quoted bid-ask spreads also show a high frequency of spreads posted at 1 tick. These evidence suggest that the tick sizes for these futures contracts are too large. Examination of the relationships between dollar spreads and dollar ticks provide further evidence that dollar spreads are constrained by the tick size. Dollar spreads are found to be positively related to dollar ticks, average quoted depth and trade price volatility, and negatively related to traded volume.

JEL Classifications: **G13**

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1 INTRODUCTION

This paper highlights the importance of security design on trading outcomes by examining the size of minimum price variation (commonly known as 'tick') of three interest rate futures traded on the Sydney Futures Exchange (SFE) and their impacts on elements of market quality. In particular, this study examines the Bank-Accepted Bill futures (BAB), 3-Year Treasury Bond futures (3-Year T-Bond), and 10-Year Treasury Bond futures (10-Year T-Bond) contracts.

A unique peculiarity of the design of these interest rate futures contracts is that market prices are quoted in yield percentage points but are converted to dollar value for daily marking-to-market and final settlement. This uniqueness lies in the pricing models of these futures contracts which indicate that their contract values (in dollars) are not linearly related to yield. Accordingly, one yield point when converted to dollars is worth differently depending on the level of the market price.[1] Since the tick sizes for these contracts are specified in yield points, it follows that the dollar values of these tick sizes also vary according to the price level. Given that bid-ask spreads have to be posted at the tick or at multiples of the tick, the direct implication is that dollar bid-ask spreads fluctuate independently of the tick size, thereby introducing new dynamics not observed in other non-interest rate futures contracts.

Consider a situation in which the bid-ask spread is constrained at the size of the minimum tick. As dollar tick increases, dollar bid-ask spread is forced to widen accordingly. This is not ideal trading condition, especially in a situation where the size of the tick is already considered too large for trading purposes. The impact of this effect is empirically examined in this paper. As this research issue has not been previously examined, this essay advances further knowledge on tick size in this regard by utilising an alternative empirical framework through which an investigation of the effects of varying dollar tick sizes is conducted.

The analysis contained in this paper is two-fold: the first examines for price clustering behaviour in the market for these futures contracts which provides evidence on whether the tick sizes are considered either too small or large by the market participants; the second analysis assesses the impact of varying dollar tick sizes on quoted depth, volume and trade price volatility.

The organisation of this study is as follows. Section 2 provides a literature review. Section 3 describes the pricing models of the futures contracts. Data and methodology are outlined in sections 4 and 5. Section 6 presents the results, and section 7 concludes.

2 LITERATURE REVIEW

The exchange-mandated minimum price variation exists since a specific discrete set of prices can contribute to better price resolution and lower negotiation costs. Given that quotes must be made at the minimum tick or multiples of the tick, prices can be resolved comparatively quicker because this effectively restricts the combinations of prices which traders can quote for bid and ask, thereby reducing information asymmetry and improving trading efficiency. However, additional trading cost is incurred through the loss in price precision. Nevertheless, traders will still prefer rounded prices if that loss is proportionally lower than the gains obtained through the decrease in negotiation costs. Traders may restrict the discrete set of prices to multiples of two or more ticks if prices cannot be resolved to the nearest minimum tick. By posting quotes using rounded prices, traders have effectively picked their own minimum price variation. Accordingly, the term price clustering describes the tendency of the bid and ask quotes to cluster at salient points greater than the minimum tick. The downside of a small tick is its implication in ordering exposure and depth because a small tick encourages quote-matching activities.

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[1] As price level decreases, the size of the dollar tick increases, and vice versa.

Conversely, price precision deteriorates if the tick size is too large, since traders are forced to pick a coarser set of prices. Moreover, given that traders are prevented from posting bid-ask spreads smaller than the tick, the spreads may be unduly constrained at the tick size, thus increasing transaction costs, with detrimental effects on trading volume.

Recent literature has focussed almost exclusively on the impact of a reduction of tick size on market quality in the equities markets, particularly in the US, where a tick size of sixteenths of a dollar was introduced in AMEX, NYSE and NASDAQ in mid-1997, effectively reducing the original tick by half. The evidence presented in the research[2] show conclusively that, as tick size is reduced, bid-ask spreads are also reduced — *prima facie* proof that the tick size was too large prior to the change. There is some evidence which show an associated deterioration of market depth, since a smaller tick does not provide as much protection to traders. Furthermore, Ronen and Weaver (1997) observed decreases in interday and intraday volatility after the tick reduction. Similar results have been documented in Canada (Bacidore, 1997; Porter and Weaver, 1997; Ahn et al., 1998; Griffiths et al., 1998), Australia (McInish and McCorry, 1997), Tokyo (Ahn et al., 2001) and Singapore (Lau and McInish, 1995).

Aitken and Comerton-Forde (2005) investigate the impact of tick size changes on the Australian equities market following the reduction of tick sizes for stocks priced below AUD$0.50 and stocks priced above AUD$10 on December 4 1995. For stocks priced below AUD$0.50, significant reduction in quoted bid-ask spreads and quoted depth, with an overall increase in liquidity were found after the reduction in tick size. In contrast, increased bid-ask spread, decreased depths and liquidity were reported for low volume stocks priced above AUD$10, while high-volume stocks experienced an increase in liquidity. The study also found no change in order exposure following the change in tick sizes, contrary to Harris (1994).

Smith et al. (2006) examine the impact of the introduction of a penny tick size on the Toronto Stock Exchange on January 29, 2001 and found no evidence of a reduction of market liquidity. Rather, the study found evidence of lower trading costs, faster time to order execution and greater price continuity.

Ahn et al. (1998) investigate the impact of decimalisation on the Toronto Stock Exchange on the competition for order flow. Reduction in bid-ask spread is documented on the TSE for TSE stocks cross-listed on the NYSE/AMEX but no evidence of change is reported on NYSE/AMEX. For TSE stocks cross-listed on NASDAQ, reduction in spreads on both stock exchanges has been reported. The study found no transfer of order flow from the US markets to the TSE following the tick size change, implying that the benefits of trading in the former is greater.

More recently, a string of studies have emerged examining the impact of tick size on stock price behaviour, not in relation to tick size changes. Whereas the studies above are conducted on a pre-post (tick reduction) design, these recent studies compared stocks with different tick sizes, primarily in the Hong Kong and Taiwan equity markets. Huang et al. (2000) is the first paper to examine the impact of tick size using this approach for the Taiwan Stock Exchange. They found evidence which suggest that smaller tick sizes are associated with lower return volatility and narrower effective bid-ask spread. Ke, Jiang and Huang (2004) expanded that study to include transaction data. Comparing firms with different tick sizes, the study

[2] AMEX: Crack (1995), Ahn, Cao and Choe (1996), Ronen and Weaver (2001). NYSE: Ricker (1998), Goldstein and Kavajecz (2000), Jones and Lipson (1999). NASDAQ: Jones and Lipson (1998). See Van Ness et al (2000) for an extensive review of existing literature.

provides similar evidence that a larger tick size is associated with wider bid-ask spread, larger volatility and more negative autocorrelation, but no significant association with trading volume was found. Chan and Hwang (2001) examine the stock market quality of the Stock Exchange of Hong Kong. Similarly, decrease in bid-ask spreads and improvement in market depth are observed to be associated with smaller tick sizes. In a related study, Fischer (2004) examines the price behaviour of the foreign exchange spot market following Swiss National Bank interventions for the period 1986 to 1995, and documents significant price clustering behaviour following such interventions. The evidence reported shows that such price clustering behaviour might have widened bid-ask spreads and therefore increased exchange rate volatility.

If the size of the tick affects the degree of price resolution, it follows that it may also influence the quality of price discovery in the market. In the first study of its type, Beaulieu et al. (2003) investigate the price discovery role of an exchange-traded fund and the futures contract for the same market index. The fund was affected by a substantial tick size reduction on the Toronto Stock Exchange on September 27, 1991. Using transaction prices as well as bid and ask quotes from the beginning of August to the end of October 1991, the study provides evidence that the fund predicts the index in the subperiod after, but not in the subperiod before, the decrease in tick size. The authors conclude that successful price discovery depends on a small tick size.

3 PRICING MODELS

This study examines trading in Australian 90-Day Bank Accepted Bill futures (BAB), 3-Year Treasury Bond futures (3YTB) and 10-Year Treasury Bond futures (10YTB) on the SFE. They are deliverable contracts, quoted at a price equivalent to 100 minus the annual percentage yield and operate on a March, June, September and December expiration cycle. The minimum price variation is 0.01 yield points for the BAB and 3YTB futures, and 0.005 yield points for the 10YTB futures. Refer to Appendix 1 for full contract specifications.

The contract values of these futures contracts are calculated as follows:

Bank Accepted Bill futures:

$$P = \frac{Face\,Value \times 365}{365 + (\frac{Yield \times Days\,to\,Maturity}{100})} \tag{1}$$

where face value is always AUD$1,000,000 and days to maturity is exactly 90 days.

3-Year Treasury Bond futures:

$$P = 1000 \times \left[\frac{c(1-v^6)}{i}] + 100v^6 \right] \tag{2}$$

and *10-Year Treasury Bond futures:*

$$P = 1000 \times \left[\frac{c(1-v^{20})}{i}] + 100v^{20} \right] \quad (3)$$

where:

i = yield percentage divided by 200

$$v = \frac{1}{(1+i)}$$

c = coupon rate divided by 2.

4 DATA

The data available for this study was provided by the SFE via SYCOM IV. Trade, quote and depth data for the nearest to maturity 90-Day Bank Accepted Bill contract, 3-Year Treasury Bond contract and the 10-Year Treasury Bond contract are used for the period 4 January 2000 to 1 February 2002. These data include the best bid and ask quotes, depths at the best bid and ask quotes, trade prices and volumes, all time-stamped to the nearest second. 15-minute snapshots were constructed from the intraday data in order to generate a high-low volatility measure at each 15-minute sampling interval.

The sample period surrounds the change in transparency that occurred on 19 January 2001 before which the limit order book was less transparent at the second and third best prices. An examination of the effect of such a change is beyond the scope of this discussion. Rather, this study uses this event to test for robustness of results, and to provide a better insight into the dynamic relationship between tick size and market quality.

5 METHODOLOGY

5.1 Price Clustering Analysis

Price clustering can be examined by generating the frequency distribution of the last digit in transaction prices. Following Ball et al. (1985), a χ^2 test is used to determine if the frequency of the occurrence of the last digit differs from a uniform distribution. Given that the last digit in the 10-Year T-Bond futures can only take on two values, 0 and 5, the previous digits of these contracts were also analysed.

Bid and ask price variations are also examined to determine if the tick size is too small or large. If the frequencies of bid and ask price variations occurring at one tick are high, this implies that the tick is too large. Conversely, clustering in these variations is expected if the tick size is too small. Bid ask spreads are analysed in similar manner to determine whether they are being constrained at the tick.

5.2 Examining the Relationship between Tick Size and Market Quality

This study uses a regression framework in which dollar ticks are regressed against market quality variables, such as average quote depth, volume and volatility. Given the transparency change on the 19 January 2001, and also given the change in coupon rates for the 3-Year and 10-Year Treasury Bond futures contracts from 12% to 6% (effective after the June 2001 contracts), the selected sample period for the regression analysis spans 19 June 2000 to 16 June 2001. This period covers the change in the level of transparency on 19 January 2001, and therefore allows the analysis to be broken down into 2 pre and post sub-periods (approximately seven and five months pre and post data respectively) for the purpose of robustness tests. The sample period is specifically chosen to end before the changes in the coupon rates for the Treasury Bond futures contracts were made effective, which would otherwise complicate the analysis. The sample includes 4 near contracts for each of the interest rate products.

As a preliminary step, the contract values of the bid and ask prices, as determined by equations (1), (2) and (3) are calculated for each futures contract. Dollar spreads are then calculated by subtracting the contract values of the bid from the ask. Dollar ticks are then calculated by dividing each dollar spread by the number of ticks at which the spread is posted at time *t*:

$$DollarTick_t = \frac{DollarSpread_t}{NumberOfTick_t} \quad (4)$$

That is, $DollarTick \subseteq DollarSpread$.

Next, the variables are tested for stationarity using the augmented Dickey-Fuller (1981) test. Table 9 shows that $DollarTick_t$ is I(1) while the other variables included in the regression are I(0). For consistency, the values of each series in the regression equation are transformed into natural logarithm form. For tick data, the regression is specified as:

$$DollarTick_{i,t} = \alpha_1 + \beta_1 TradeSize_{i,t} + \gamma_1 AvDepth_{i,t} + \delta_1 DollarTick_{i,t-1} + \varepsilon_t \quad (5)$$

where

$DollarTick_{i,t}$ = the dollar tick of futures contract *i* over interval *t*

$TradeSize_{i,t}$ = trade size of futures contract *i* over interval *t*

$AvDepth_{i,t}$ = the average depth of futures contract *i*, defined as $\frac{BidDepth_{i,t} + AskDepth_{i,t}}{2}$, over interval *t*

$DollarTick_{i,t-1}$ = the lagged one-period dollar tick of futures contract *i* over interval *t*

Depth and trade size are included in the specification, given that they are two visible elements of market quality. The lagged one-period first difference of dollar tick is also included to model the dynamics in the relationship and to control for serial correlation in the error term.

Five-minute interval data is also generated, so as to enable a per interval calculation of trade price volatility. The time-weighted sampling method used in this study and applied to all variables in the regression follows the methodology developed in McInish and Wood (1992). Formally, for series $\{Y_t\}$, the time-weighted value is calculated for each 5-minute interval as follows:

$$\sum_{i=1}^{N} \frac{Y_t(t_{i+1} - t_1)}{t_{N+1} - t_1} \tag{6}$$

$t_{N+1} - t_1$ is the total length of time in which all observations in $\{Y_t\}$ series in the 5-minute interval are alive, given N observations occurring at time t_i, $i = 1, 2, .., N$.

The regression specification used for the time-weighted data is the same as equation (5) except for the inclusion of price volatility, being the variance of trade price calculated at each 5-minute interval for each futures contract. The regression model is specified as follows:

$$\begin{aligned} DollarTick_{i,t} &= \alpha_1 + \beta_2 TradeSize_{i,t} + \gamma_2 AvDepth_{i,t} + \mu_2 Volat_{i,t} \\ &\quad + \delta_2 DollarTick_{i,t-1} + \varepsilon_t \end{aligned} \tag{7}$$

where $Volat_{i,t}$ is the variance of trade price of futures contract *i* over interval *t*.

6 RESULTS

6.1 Analysis of Frequency Distributions

Table 1 presents the frequency distributions of bid and ask quote variations as well as the quoted bid-ask spread across the first three ticks over the sample period 4 January 2000 to 1 February 2002.

Panel A of Table 1 reports the results for the Bank-Accepted Bill futures contract. The results presented show that bid and ask quote revisions vary at 1 tick for at least 94% of all quote revisions, and at least 97% of all quote revisions up to 3 ticks throughout the entire sample periods. There is evidence to suggest that the frequency distributions have significantly reduced after the change in transparency on 19 January 2001. There is very strong evidence that the bid-ask spreads are constrained at the tick, with at least 98% of all bid-ask spreads posted at 1 tick, though this frequency is reduced slightly after the change in transparency. The evidence presented implies that the tick size is too large.

Table 1
Frequency Distribution

This table presents the frequency distributions of bid/ask quote variations and the bid-ask spread across 3 ticks for the period 4 January 2000 to 1 February 2002. Panels A, B and C present the results for the Bank-Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts, respectively. The "Pre" and "Post" columns display results before and after the change in transparency on 19 January 2001. This change is tested for significance with results reported in the respective "*t-stat*" *columns.* The minimum price variation is 0.01 yield points for the BAB and 3-Year Treasury Bond futures contracts, and 0.005 yield points for the 10-Year Treasury Bond futures contract.

	Bid Variations				*Ask Variations*				*Bid-Ask Spread*			
	Pre	*Post*	*t-stat*		*Pre*	*Post*	*t-stat*		*Pre*	*Post*	*t-stat*	
Panel A: BAB												
1 tick	95.00%	93.98%	-3.09	**	94.99%	94.20%	-2.18	*	98.24%	97.16%	-2.95	**
2 ticks	2.84%	2.84%	-0.02		3.11%	3.53%	1.57		1.46%	1.34%	-1.99	*
3 ticks	0.83%	0.76%	-0.28		0.81%	0.63%	-0.97		0.14%	0.19%	1.97	*
total	98.67%	97.58%			98.91%	98.36%			99.84%	98.69%		
Panel B: 3Y T-Bond												
1 tick	97.91%	97.33%	-3.83	**	97.73%	97.46%	-1.76		99.27%	98.26%	-3.00	**
2 ticks	1.00%	1.40%	3.63	**	1.04%	1.25%	1.96		0.61%	0.64%	0.30	
3 ticks	0.38%	0.30%	-0.34		0.47%	0.36%	-1.09		0.05%	0.06%	0.26	
total	99.29%	99.03%			99.27%	99.08%			99.93%	98.96%		
Panel C: 10Y T-Bond												
1 tick	90.31%	85.68%	-13.84	**	89.37%	83.99%	-15.55	**	96.54%	94.49%	-5.69	**
2 ticks	7.00%	10.45%	11.87	**	7.63%	11.61%	13.25	**	3.03%	3.73%	2.12	*
3 ticks	1.00%	1.60%	5.14	**	1.13%	2.05%	7.18	**	0.26%	0.43%	1.67	
total	98.31%	97.73%			98.13%	97.65%			99.83%	98.65%		

* denotes significance at the 0.01 level
** denotes significance at the 0.001 level

Panel B of Table 1 presents the results of frequency distributions for the 3-Year Treasury Bond futures contract. Across the entire sample period, bid and ask quote revisions vary at 1 tick at least 97% of all quote revisions. Bid and ask quote variations up to 3 ticks comprise at least 99% of all quote variations for the whole period. After the change in transparency, these frequencies have reduced and significantly so for bid quote variations. Bid-ask spreads are found to have been posted at 1 tick 99.27% and 98.26% of all spreads before and after the transparency change, suggesting that the spreads are constrained by the size of the tick.

It is noted that a reduction in coupon rate in June 2001 may have contributed to the decline in the frequency distributions at 1 tick in the period after transparency change. Though not reported, dollar tick has been found to reduce by about AUD$3 on average after the coupon rate reduction. It is also possible that these reductions in frequency distributions in the second period are caused by the change in transparency as well. Nevertheless, the results suggest strongly that the tick size is too large.

Panel C of Table 1 documents the results of frequency distributions for the 10-Year Treasury Bond futures contract. Given a minimum price variation of 0.005 yield points (half the tick size of the other two futures contracts), the frequency distributions presented are not as high compared to other two futures contracts. Bid and ask quote variations are posted at 1 tick approximately 90% of the time, but these frequencies reduced significantly in the second period. On average, dollar tick has reduced by approximately AUD$7 after a reduction in coupon rate in June 2001. Given a cheaper tick, a reduction in quote variations at 1 tick is expected. Again, it is entirely possible that these reductions are additionally influenced by the transparency change. The frequency of spreads posted at 1 tick has significantly reduced as well, though the frequency remains around 95%. The evidence presented implies that the tick size is too large, even in the second period.

Table 2
Frequency Distribution – Last Digit of Trade Price

This table reports the frequency distribution of the last digit of trade price for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts respectively for the period 4 January 2000 to 1 February 2002. The minimum price variation is 0.01 yield points for the BAB and 3-Year Treasury Bond futures contracts, and 0.005 yield points for the 10-Year Treasury Bond futures contract. Panels A and B present the results before and after the change in transparency on 19 January 2001. The χ^2 test is used to test for uniform distribution (null hypothesis: frequencies not uniformly distributed).

	BAB	*3YTB*	*10YTB*
Panel A: Pre			
0	10.42%	9.67%	51.91%
1	9.82%	9.01%	
2	9.65%	9.40%	
3	9.10%	9.67%	
4	9.74%	10.50%	
5	8.95%	10.02%	48.09%
6	9.43%	10.07%	
7	11.61%	10.65%	
8	10.75%	11.31%	
9	10.52%	9.70%	
χ^2	423.83**	984.68**	368.98**
Panel B: Post			
0	9.86%	9.77%	52.90%
1	9.00%	9.67%	
2	9.49%	11.14%	
3	9.84%	11.44%	
4	10.19%	10.61%	
5	9.38%	9.00%	47.10%
6	10.71%	8.98%	
7	10.91%	9.23%	
8	10.51%	10.63%	
9	10.10%	9.53%	
χ^2	249.84**	1952.69**	841.87**

** denotes significance at the 0.001 level

As discussed previously, the results documented strongly suggest that the tick sizes are too large for all 3 futures contracts. To confirm this further, the frequency distributions of the last digit of trade price for these contracts are investigated for signs of price clustering. These frequencies would be expected to be uniformly distributed, i.e. no evidence of price clustering, if the tick size is too large. A χ^2 test is utilized to test for uniform distribution in this regard. The results are presented in Table 2.

Table 2 reports results which show that the frequency distributions of the last digit of trade price for the futures contracts are statistically uniform in both sample periods. There is no evidence of price clustering which otherwise would show that the tick size is too small. Given that the last digit of trade price for the 10-Year Treasury Bond futures contract can take only the values 5 or 0, the last two digits of trade price are also examined for uniform distribution, with results presented in Table 3.

These results reported in Table 3 are consistent with the evidence presented previously.

Table 3
Frequency Distribution –Last Two Digits of Trade Price

This table reports the frequency distribution of the last two digits of trade price for the 10-Year Treasury Bond futures contract for the period 4 January 2000 to 1 February 2002. The minimum price variation is 0.005 yield points for the 10-Year Treasury Bond futures contract.

	Pre	*Post*
0	5.52%	5.17%
05	5.08%	4.29%
10	5.26%	4.92%
15	5.09%	4.40%
20	5.49%	5.07%
25	5.09%	4.52%
30	5.67%	5.26%
35	4.93%	4.98%
40	5.45%	5.68%
45	4.86%	5.29%
50	4.89%	5.65%
55	4.46%	4.82%
60	5.18%	5.49%
65	4.68%	4.95%
70	4.86%	5.53%
75	4.49%	4.69%
80	4.76%	5.14%
85	4.66%	4.82%
90	4.82%	4.97%
95	4.74%	4.34%
χ^2	1142.49**	1657.64**

** denotes significance at the 0.001 level

From the results reported above, there is strong evidence to suggest that the tick sizes for the Bank-Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts are too large. The frequencies of bid and ask quote variations posted at the minimum tick before and after the change in transparency are excessively high — price precision is thereby sacrificed. Additionally, the frequency of bid-ask spreads posted at the minimum tick in both periods strongly suggest that the "true" spreads are smaller than the tick size.

6.2 Impact of Tick Size on Market Quality

Table 4 presents the descriptive statistics of the regression variables based on the tick data and 5-minute time-weighted data, for the sample period 19 June 2000 to 16 June 2001. Section A presents the summary statistics for tick data, and section B reports the summary statistics for time-weighted data. The dollar ticks (and hence dollar bid-ask spreads) for each futures contract differ in value as they are calculated differently. More importantly, there is evidence which show that the mean of the dollar tick is very close to the mean of dollar bid-ask spread for all interest rate futures, confirming evidence presented previously that the bid-ask spread is constrained at the tick. In particular, the values of both variables are identical for 3-Year Treasury Bond futures. Volatility, calculated at each 5-minute interval, appears to be subdued overall. This is expected given that majority of price changes occur at the tick size.

Table 5 reports the overall parameter estimates using both tick data and time-weighted data for the Bank Accepted Bill futures contract, 3-Year Treasury Bond futures contract and 10-Year Treasury Bond futures contract for the period 19 June 2000 to 16 June 2001.

Table 4
Descriptive Statistics

This table presents descriptive statistics of regression variables for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts respectively for the period 19 June 2000 to 16 June 2001. Sections A and B report the descriptive statistics for tick data and time-weighted data respectively. These statistics are calculated for level variables. Panels A, B and C report the results for the Bank-Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts, respectively. The "Level" and "Natural Log" columns display results before and after the application of natural logarithm. "Dollar Spread" is calculated by subtracting the contract value of bid quote from the contract value of ask quote, and expressed in Australian Dollars. "Dollar Tick" is calculated by dividing dollar spread by the number of tick at which it is posted, and expressed in Australian Dollars. "Average Depth" is the mean of bid and ask depths. "Trade Size" is the observed trade size. "Volatility" is generated over each 5-minute interval by calculating the variance of trade price.

Section A: Tick Data

	Dollar Tick		***Dollar Spread***		***Average Depth***		***Trade Size***	
	Level	*Natural Log*	*Level*	*Natural Log*	*Level*	*Natural Log*	*Level*	*Natural Log*
Panel A: BAB								
Mean	23.99	3.18	24.83	3.20	467.12	5.91	42.83	2.89
Median	24.00	3.18	24.00	3.18	405.00	6.00	25.00	3.22
Std Deviation	1.09	0.019	5.28	0.134	313.38	0.75	53.67	1.55
Panel B: 3Y T-Bond								
Mean	30.28	3.41	30.28	3.41	645.93	6.23	32.24	2.66
Median	30.35	3.41	30.35	3.41	583.00	6.37	19.00	2.94
Std Deviation	1.10	0.024	5.68	0.029	424.71	0.78	44.82	1.44
Panel C: 10Y T-Bond								
Mean	48.27	3.88	49.14	3.89	72.60	4.00	10.68	1.64
Median	47.77	3.87	47.83	3.87	59.50	4.09	5.00	1.61
Std Deviation	1.58	0.032	6.64	0.098	65.00	0.82	15.53	1.23

Table 4 (con't):

Section B: Time-Weighted Data

	Dollar Tick		***Dollar Spread***		***Average Depth***		***Trade Size***		***Volatility***	
	Level	*Natural Log*	*Level*	*Natural Log*	*Level*	*Natural Log*	*Level*	*Natural Log*	*Level*	*Natural Log*
Panel A: BAB										
Mean	23.99	3.18	25.04	3.21	433.63	5.80	27.23	2.59	6.08E-04	6.08E-04
Median	23.99	3.18	24.00	3.18	372.43	5.90	22.95	2.83	0	0
Std Deviation	1.10	0.024	5.49	0.139	301.75	0.78	45.31	1.49	0.007	0.007
Panel B: 3Y T-Bond										
Mean	30.27	3.41	30.27	3.41	525.83	5.90	24.45	2.18	1.73E-05	1.73E-05
Median	30.32	3.41	30.32	3.41	454.36	6.10	15.30	2.28	0	0
Std Deviation	1.12	0.019	5.69	0.019	406.20	0.94	30.37	1.33	1.18E-04	1.18E-04
Panel C: 10Y T-Bond										
Mean	48.32	3.87	49.91	3.90	56.78	3.70	9.23	1.48	5.28E-06	5.28E-06
Median	47.82	3.87	47.93	3.87	46.53	3.80	5.84	1.46	0	0
Std Deviation	1.63	0.033	8.07	0.118	46.77	0.84	11.92	1.02	2.72E-05	2.72E-05

Panel A of Table 5 presents results of regression analysis performed on tick data. Though the adjusted *R*-square values are low, the *F*-statistics show that the regressions are all significant. There is weak evidence that dollar tick is inversely related to trade size for all contracts, suggesting that an increase in dollar tick (and transaction cost accordingly) will compromise trade size. Average quoted depth is documented to be positively and significantly related to dollar tick for all three futures contracts. These results are consistent with Harris (1996), that traders are more willing to provide greater depth as more protection (through increases in dollar tick) is available against quote-matching activities.

Panel B of Table 5 reports results of regression analysis conducted on time-weighted data. Given the loss of data, a loss in dynamics and thus of statistical significance are expected. Nevertheless, the evidence presented in Panel B shows that the structural relationships between the regressors and dollar tick are the same as shown in Panel A. That is, a significant and positive relationship between dollar tick and average quote depth, and a negative relationship between trade size and dollar tick, are documented for all futures. The inclusion of a volatility measure in the regression specification provides further insight into its relationship with dollar tick.

Table 5
Overall Regression Analysis by Tick and Time-Weighted Data

This table reports the results of regression analysis by which the change in dollar tick is regressed against changes in traded volume, average depth, volatility and one own lag, for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts respectively over the period 19 June 2000 to 16 June 2001. The regression specification applied to tick data (shown in Panel A) is specified as:

$$DollarTick_{i,t} = \alpha_1 + \beta_1 TradeSize_{i,t} + \gamma_1 AvDepth_{i,t} + \delta_1 DollarTick_{i,t-1} + e_t$$

The regression specification applied to time-weighted data (shown in Panel B) is:

$$DollarTick_{i,t} = \alpha_2 + \beta_2 TradeSize_{i,t} + \gamma_2 AvDepth_{i,t} + \mu_2 Volat_{i,t} + \delta_2 DollarTick_{i,t-1} + e_t$$

The t-statistics are reported in parentheses. Results are Newey-West (1987) adjusted for heteroskedasticity and autocorrelation.

	α	*Trade Size*	*Average Depth*	*Volatility*	*$DollarTick_{t-1}$*	*Adj-R^2*	*d-stat*	*F-stat*		*N*
Panel A: Tick Data										
BAB	2.56E-06	-1.43E-07	2.90E-07	-	0.265	0.07	2.08	1870.16	**	74115
	(0.43)	(-0.83)	(3.52)**		(39.98)**					
3-Year T-Bond	3.12E-06	-3.72E-08	9.31E-07	-	0.213	0.06	2.05	4129.37	**	255134
	(0.54)	(-0.23)	(2.84)**		(40.41)**					
10-Year T-Bond	6.43E-06	-1.26E-06	3.50E-06	-	0.168	0.05	2.04	3178.40	**	228297
	(0.29)	(-1.67)	(4.04)**		(43.46)**					
Panel B: Time-Weighted Data										
BAB	3.36E-05	-1.57E-06	6.17E-07	0.06	0.301	0.19	2.19	781.82	**	13527
	(0.56)	(-0.87)	(2.50)*	(1.28)	(15.83)**					
3-Year T-Bond	9.91E-05	-9.43E-07	2.69E-07	2.78	0.283	0.08	2.07	600.13	**	26660
	(0.59)	(-0.61)	(2.33)*	(1.04)	(15.66)**					
10-Year T-Bond	1.76E-03	1.76E-05	1.05E-05	10.43	0.231	0.09	2.03	443.08	**	28996
	(0.29)	(-1.37)	(2.20)*	(1.74)	(10.06)**					

* denotes significance at the 0.05 level
** denotes significance at the 0.01 level

Table 6
Regression Analysis –Tick Data

This table reports the results of regression analysis by which the change in dollar tick is regressed against changes in traded volume, average depth and one own lag, for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts respectively over the periods 19 June 2000 to 18 January 2001 ("pre" period), and 20 January to 16 June 2001 ("post" period). The regression specification applied is stated as

$$DollarTick_{i,t} = \alpha_1 + \beta_1 TradeSize_{i,t} + \gamma_1 AvDepth_{i,t} + \delta_1 DollarTick_{i,t-1} + e_t$$

Panels A and B present results before and after the change in transparency on 19 January 2001, respectively. The *t*-statistics are reported in parentheses. Results are Newey-West (1987) adjusted for heteroskedasticity and autocorrelation.

	α	*Trade Size*	*Average Depth*	$DollarTick_{t-1}$	$Adj\text{-}R^2$	*d-stat*	*F-stat*		*N*
Panel A: Pre									
BAB	2.90E-06 (0.36)	-2.69E-07 (-1.22)	2.16E-07 (2.12)*	0.257 (31.70)**	0.07	2.08	988.20	**	41861
3-Year T-Bond	9.56E-06 (1.29)	-1.95E-08 (-0.27)	7.64E-07 (8.88)**	0.218 (39.41)**	0.05	2.06	2327.53	**	138707
10-Year T-Bond	2.91E-05 (1.06)	-1.10E-06 (-0.66)	3.31E-06 (4.05)**	0.199 (35.74)**	0.05	2.04	1813.32	**	130375
Panel B: Post									
BAB	1.98E-06 (0.21)	-3.26E-08 (-0.13)	4.22E-07 (3.05)**	0.263 (-6.68)**	0.08	2.09	886.41	**	32254
3-Year T-Bond	-4.63E-06 (-0.50)	-5.34E-08 (-0.21)	1.15E-06 (11.15)**	0.209 (7.51)**	0.05	2.04	1813.45	**	116427
10-Year T-Bond	-2.37E-05 (-0.66)	-9.24E-07 (-0.38)	5.33E-06 (3.22)**	0.200 (26.96)**	0.06	2.03	1364.59	**	97922

* denotes significance at the 0.05 level
** denotes significance at the 0.01 level

There is evidence that shows a positive relationship between dollar tick and volatility, though the results are not significant. For both sets of data, the estimated coefficients for trade size and average quote depth are less than one, suggesting that the variables are not elastic to changes in dollar tick.

Table 6 presents results of regression analysis conducted on tick data separated into two sample periods covering the pre and post transparency change for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts. The "pre" period covers 19 June 2000 to 18 January 2001 while the "post" period spans from 20 January 2001 to 16 June 2001.

Panels A and B of Table 6 report results for the sample periods before and after the change in transparency respectively. In both sub-samples, significant results are documented for all three contracts. Dollar tick is found to be positively and significantly related to average quote depth for all contracts. Again, there is weak evidence to suggest that trade size is negatively related to dollar tick. Similarly, average quote depth is positively and significantly related to dollar tick for all contracts. The documented results imply that the structural relationships between dollar ticks, trade size and average quoted depth are consistent even after the change in transparency.

Table 7
Regression Analysis –Time-Weighted Data

This table reports the results of regression analysis by which the change in dollar tick is regressed against changes in traded volume, average depth, volatility and one own lag, for the Bank Accepted Bill, 3-Year Treasury Bond and 10-Year Treasury Bond futures contracts respectively over the periods 19 June 2000 to 18 January 2001 ("pre" period), and 20 January to 16 June 2001 ("post" period). Variables are time-weighted in 5 minute intervals. The regression is specified as:

$$DollarTick_{i,t} = \alpha_2 + \beta_2 TradeSize_{i,t} + \gamma_2 AvDepth_{i,t} + \mu_2 Volat_{i,t} + \delta_2 DollarTick_{i,t-1} + e_t$$

Panels A and B present results before and after the change in transparency on 19 January 2001, respectively. The *t*-statistics are reported in parentheses. Results are Newey-West (1987) adjusted for heteroskedasticity and autocorrelation.

	α	*Trade Size*	*Average Depth*	*Volatility*	*DollarTick*$_{t-1}$	*Adj-*R^2	*d-stat*	*F-stat*		*N*
Panel A: Pre										
BAB	1.68E-05 (0.59)	-1.30E-06 (-1.50)	1.13E-07 (2.23)*	0.22 (1.33)	0.291 (15.80)**	0.17	2.17	378.26	**	7465
3-Year T-Bond	9.51E-05 (1.53)	-5.05E-07 (-0.25)	8.65E-07 (2.11)*	2.69 (1.41)	0.313 (12.43)**	0.10	2.10	417.49	**	14835
10-Year T-Bond	2.39E-04 (1.19)	-3.52E-05 (-1.91)	1.54E-05 (2.27)*	12.42 (1.53)	0.261 (10.04)**	0.08	2.05	338.50	**	16671
Panel B: Post										
BABs	1.43E-05 (0.39)	-2.33E-06 (-1.56)	2.11E-06 (2.26)*	0.05 (1.32)	0.342 (16.53)**	0.21	2.21	410.89	**	6062
3-Year T-Bond	-4.43E-05 (-0.46)	-1.45E-06 (-0.61)	4.21E-07 (2.05)*	3.90 (0.37)	0.257 (5.53)**	0.07	2.04	209.63	**	11825
10-Year T-Bond	-7.7E-04 (-0.66)	-1.20E-05 (-1.36)	3.79E-06 (2.37)*	10.48 (1.27)	0.196 (5.03)**	0.09	2.02	233.0	**	12325

* denotes significance at the 0.05 level
** denotes significance at the 0.01 level

Table 7 presents results of regression analysis conducted on 5-minute time-weighted data separated into two sub-samples by the date of the transparency change for the three interest rate futures contracts. The "pre" period spans 19 June 2000 to 18 January 2001 while the "post" period covers 20 January 2001 to 16 June 2001. Significant results are documented for all three contracts in both sub-samples. Results presented in this table confirm earlier findings on the relationships between the variables.

Overall, there is strong evidence to suggest that the average quoted depth is positive and significantly related to dollar tick, consistent with Harris (1996). However, as the results are not elastic to changes in dollar tick, the effects are unlikely to be economically significant. There is weak evidence to imply a negative relationship between trade size and dollar tick. Positive relationship between dollar tick and price volatility is found (albeit not significant) for all futures contracts. With the exception for price volatility, the parameter estimates for both trade size and average quoted depth are less than one, implying that they are not elastic to dollar tick changes. The empirical results are robust to the change in transparency on January 19 2001.

7 CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

This paper highlights one of the important links between security design and trading outcomes through an investigation of the tick size, as well as the relationship between tick size and market quality variables such as quoted spread, depth, volatility and volume of the Bank Accepted Bill futures contract, 3-Year Treasury Bond futures contract and 10-Year Treasury Bond futures contract traded on the Sydney Futures Exchange. The evidence presented in this study is particularly relevant to policy makers and regulators.

Evidence presented from the analysis of the frequency of bid and ask quote variations show a high percentage of variations posted at one tick for all three futures contracts. Analysis of the quoted spreads also show a high frequency of spreads posted at the minimum tick. This significant evidence strongly suggests that the tick sizes for all interest rate futures contracts are too large.

The examination of the relationship between dollar tick and market quality variables shows that an increase in dollar tick would adversely impact market quality. Using the periods before and after the change of transparency on 19 January 2001 for robustness, the evidence presented shows that dollar tick is significantly and positively related to average quoted depth, though the parameter estimates suggest that average quoted depth is not elastic to changes in dollar tick, given that the estimates are all less than one. Therefore, the effects are not likely to be economically significant. Nevertheless, this finding is consistent with Harris (1996) who argues that as dollar tick firms quote matching activities become more expensive to conduct. Market participants are therefore more confident in posting bigger depth. There is weak evidence that shows that dollar tick is positively related to trade price volatility, and negatively related to trade size. This is consistent with previous findings on the relationships between bid-ask spreads, volatility and volume.

Given the evidence that bid-ask spreads are often posted at the tick size, the implication is that dollar spreads are forced to widen as dollar tick becomes more expensive given varying yield levels. On the other hand, a more expensive dollar tick provides better protection for traders from quote-matching activities. Ideally, an unvarying dollar tick big enough to discourage quote-matching activities is preferred. The former is relatively easy to implement, but determining the tick size which balances the degree of price resolution with the level of quote-matching activities will prove to be difficult and remains a potential subject for future research.

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Appendix 1: Contract Specifications for Bank Accepted Bill Futures, 3 Year and 10 Year Treasury Bond Futures Contracts

Table 8
Contract Specifications

	Contract Unit	*Contract Months*	*Minimum Price Variation*	*Last Trading Day*	*Final Settlement Price*	*Trading Hours*	*Settlement Day*
90 Day Bank Accepted Bills futures	AUD$1m face value 90-Day Bank Accepted Bills of exchange or EBAs	March/June/ September/December up to twenty quarter months or 5 years ahead.	0.01% yield points	Business day immediately prior to settlement day.	Last trading price as at 12.00pm on last trading day.	5.10pm – 7.00am and 8.30am – 4.30pm (during US daylight saving time) 5.10pm – 7.30am and 8.30am – 4.30pm (during US non daylight saving time)	2nd Friday of expiration month.
3-Year Commonwealth Treasury Bond futures	Commonwealth Government Treasury Bonds with a face value of AUD$100,000, a coupon rate of 6% (previously 12% until March 2001) per annum and a term of maturity of 3 years.	March/June/ September/December up to two quarter months ahead.	0.01% yield points	15th day of expiration month	The arithmetic mean, taken at 9.45am, 10.30am and 11.15am on the last trading day by 10 randomly selected dealers for each time.	Same as above.	The business day after expiration.
10 Year Commonwealth Treasury Bond futures	Commonwealth Government Treasury Bonds with a face value of AUD$100,000, a coupon rate of 6% (previously 12% until March 2001) per annum and a term of maturity of 10 years.	March/June/ September/December up to two quarter months ahead.	0.005% yield points	15th day of expiration month	Same as above.	Same as above.	The business day after expiration.

Appendix 2: Unit Root Tests

Table 9
Unit Root Tests

This table presents the unit root results performed on variables included for regression analysis for each futures contract as shown in Panels A, B and C. The augmented Dickey-Fuller (1981) test with drift and time trend, specified as $\Delta y_t = \alpha_1 + \varphi_1 t + \delta_1 y_{t-1} + \sum_{k=1}^{k} \rho_1 \Delta y_{t-k} + e_t$ is used to test the null hypothesis that δ = 0. Lag parameter, *k*, is estimated via Schwarz info criterion (k_{max} = 100). MacKinnon's (1996) critical values used to test the null are -3.13 (at 0.01), -3.41 (at 0.05) and -3.96 (at 0.01).

	Level		***First Difference***		***Conclusion***
	δ	t_δ	δ	t_δ	
Panel A: BAB					
DollarTick	0	-2.28	-4.53	-55.37	I(1)
Volume	-0.57	-46.60	-	-	I(0)
AvDepth	-0.06	-30.29	-	-	I(0)
Volat	-0.75	-44.19	-	-	I(0)
Panel B: 3-Year T-Bond					
DollarTick	0	-1.16	-2.10	-138.58	I(1)
Volume	-0.51	-63.91	-	-	I(0)
AvDepth	-0.03	-41.50	-	-	I(0)
Volat	-1.00	-82.79	-	-	I(0)
Panel B: 10-Year T-Bond					
DollarTick	0	-1.43	-1.41	-159.60	I(1)
Volume	-0.44	-58.47	-	-	I(0)
AvDepth	-0.08	-50.88	-	-	I(0)
Volat	-1.00	-85.06	-	-	I(0)