THE INTRADAY BEHAVIOR OF MARKET DEPTH IN A COMPETITIVE DEALER MARKET: A NOTE

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Abstract

This paper is the first to examine the intraday behaviour of quoted depth in a competitive dealer market. In sharp contrast to previous research which focuses on specialist markets, quoted depth is lowest at the open of trading, plateaus around the middle of the day, and then dramatically increases in the final hours of trading, peaking at the close. This peak in quoted depth coincides with a narrowing in bid-ask spreads, and is contrary to intraday patterns documented for specialist markets. We conclude that the increase in depth and narrowing of bid-ask spreads at the close is driven by dealers rebalancing inventories to achieve target inventory levels in a competitive market.

1. Introduction

This paper examines intraday patterns in quoted depth in a competitive dealer market. Lee, Mucklow and Ready (1993) examine intraday patterns in quoted depth on the NYSE (a specialist market), and document a "reverse U-pattern".[1] They extend earlier literature examining market liquidity measured via bid-ask spreads, arguing that depth captures a second dimension of liquidity (Harris, 1990). Lee et al. (1993) also examine intraday patterns in bid-ask spreads on the NYSE and document a U-shaped pattern, supporting an earlier finding by McInish and Wood (1992). The intraday pattern in quoted depth and bid-ask spreads is expected to be the reflection of each other given they are both proxies for liquidity, and are driven by the same underlying determinants. These papers argue that the elevation in bid-ask spreads and decline in quoted depth at the *end* of the day results from the market power of specialists, who are able to extract economic rents from traders during periods of high transaction demand and is consistent with the monopoly market power model of Brock and Kleidon (1992).[2]

Chan, Christie and Schultz (1995) examine intraday patterns in quoted bid-ask spreads on Nasdaq, which is a competitive dealer market. They document a narrowing of quoted bid-ask spreads around the market close. Chan, Chung and Johnson (1995) examine quoted bid-ask spreads on the Chicago Board Options Exchange (CBOE) which is also a competitive dealer market, and corroborate the findings of Chan, Christie and Schultz (1995). Chan, Christie and Schultz (1995) argue that the narrowing of quoted bid-

[1] They examine depth quoted by the NYSE specialist, and "assume that these are a reasonable proxy for the overall level of market liquidity" (Lee et al., page 356)

[2] Li, Van Ness and Van Ness (2005) examine the interaction between liquidity provided by the limit order book and the specialist in their analysis of the patterns in intraday depth on the NYSE.

ask spreads towards the close is driven by competition among dealers seeking to manage their inventory.

The literature attributes the conflicting intraday patterns in quoted bid-ask spreads between competitive dealer and specialist markets to differences in market structure between the NYSE, Nasdaq and the CBOE. Chan, Christie and Schultz (1995) appeal to structural differences between Nasdaq and the NYSE to help explain the narrowing of bid-ask spreads near the close that they document on Nasdaq. Chan, Chung and Johnson (1995) argue that elevated bid-ask spreads on the NYSE, and the narrowing of bid-ask spreads on the CBOE at the close, is due to competition amongst market makers on the CBOE. This competition is diminished by the role of the specialist on the NYSE. Both studies argue the absence of market power among dealers as contributing to the absence of a widening in bid-ask spreads in competitive markets at the close.

While several studies examine intraday patterns in quoted depth for specialist markets (NYSE), intraday patterns in quoted depth in competitive dealer markets are yet to be examined.[3] Chung and Zhao (2004b) document an intraday U-shaped pattern in quote *revisions* by Nasdaq dealers, arguing that this reflects inventory management around the open and close of trading by dealers.[4] Chung and Zhao (2004a) also present evidence that dealer behaviour on Nasdaq leads to a negative correlation between quoted

[3] Brockman and Chung (1999), Ahn, Bae and Chan (2001) and Biais, Hillion and Spatt (1995) document similar intraday patterns to the NYSE for the Stock Exchange of Hong Kong and the Paris Bourse (which are both order driven markets).

[4] Pirrong (1996) offers an intraday analysis of depth. However it is limited in that without access to order book data it proxies for depth by modelling price changes across fifteen minute intervals. Order book data used in this study is much richer and allows limit order book depth to be measured precisely from the quotes prevailing in the order book.

bid-ask spreads and quoted depth.[5] This corroborates Lee et al.'s (1993) finding that the intraday pattern in quoted bid-ask spreads and quoted depth are the reflection of one another. If bid-ask spreads in competitive dealer markets tighten at the end of the day due to inventory management by dealers, then quoted depth should deepen towards the close of trade in a competitive dealer market.[6] This paper provides the first thorough examination of intraday patterns in quoted depth in a competitive dealer market where dealers compete with limit order flow (specifically the Sydney Futures Exchange).

The remainder of the paper is organised as follows. Section 2 describes the data and method. Section 3 presents results and Section 4 concludes. A summary of the institutional detail of the SFE is provided in the Appendix.

2. Data and Method

Data for this study encompasses trading in the three major interest rate futures contracts traded on the SFE; 90 Day Bank Accepted Bill futures (BAB), 3-Year Bond futures and 10-Year Bond futures. The data is sourced from Reuters, and extends from 1 February, 2001 to 31 December, 2004. Reuters provides minute by minute snapshots of the market for each of the three contracts. The dataset includes fields detailing the last trade price in the minute, prevailing bid and ask quotes and quoted depth at the end of

[5] Surprisingly, the paper does not document an intraday pattern in quoted depth.

[6] Dealers attempting to reduce exposure before market close would generally reduce their quoted depth leading up to the market close. There are two forces interacting here. First, dealers will reduce the depth they quote approaching the close in order to limit their exposure to informed traders who are known to trade around the close (Admati and Pfleiderer, 1988). Second, competition among dealers may lead to increases in the depth quoted at competitive prices in order to meet their target inventory level prior to close (Chan, Chung and Johnson, 1995). Which effect dominates the other is left as an empirical issue.

each minute, traded volume and the number of trades over the minute. Consistent with previous research, analysis is restricted to daytime trading in the near term contract.[7]

The first step in the analysis is to document intraday patterns in bid-ask spreads to test whether this variable behaves similarly to other competitive dealer markets. The intraday pattern in quoted depth is then documented to determine whether depth in a competitive dealer market behaves differently to depth in a specialist market.

The bid-ask spread is measured at each minute, *t*, and reported in ticks by dividing by the minimum tick size for each contract, *i*, as follows:

$$BAS_t = \frac{Ask_t - Bid_t}{MinimumTick_i} \tag{1}$$

Volume is measured as the number of contracts traded on market across each one minute interval. Volatility is estimated as the absolute value of the price change between successive one minute intervals and is measured in terms of each contracts minimum tick;

$$Volatility_t = \mid price_t - price_{t-1} \mid \tag{2}$$

Quoted depth is measured as the average of the volume of contracts available at both the *best* bid and the *best* ask at the end of each one-minute interval;

$$Depth_t = \frac{Volume\,at\,best\,bid_t + Volume\,at\,best\,ask_t}{2} \tag{3}$$

[7] See Frino and Hill (2001).

Following Chan, Chung and Johnson (1995), each variable is standardized by subtracting the mean and dividing by the standard deviation for the day on which it is observed. To test the significance of intraday patterns in quoted depth, bid-ask spreads, volume and volatility, standardized variables are regressed on a set of intraday dummy variables. For quoted depth, the parameters of the following model are estimated using OLS:

$$st(depth_t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k D_k + \varepsilon_t \qquad (4)$$

Here $st(depth_t)$ is the standardized quoted depth occurring in interval t, n is the number of intervals in the day and D_k is a time-of-day dummy variable equal to one if observation t falls in interval k, otherwise zero. The regression is repeated for bid-ask spreads, volume and volatility. The 30-minute interval 12:30 p.m. – 13:00 p.m. is excluded in constructing time-of-day dummy variables. Using the procedure described in Newey and West (1994), t-statistics are adjusted for heteroskedasticity and autocorrelation. In addition, t-statistics are compared to a large sample size adjusted critical t-value, as outlined in Johnstone (2005).

3. Results

Figure 1 documents intraday patterns in quoted bid-ask spreads for the three interest rate futures contracts. Quoted bid-ask spreads for 90 day BAB's are wide at the opening (1.4 standard deviates above the mean), decline across the next two half hourly intervals (to -0.39 standard deviates below the mean), remain stable across the middle part of the day and then narrow in the final hour prior to the close. Quoted bid-ask

spreads are at their lowest level in the final 30 minutes of trading, reaching –1.16 standard deviates below the mean. Both 3-Year and 10-Year bond futures follow similar patterns, with spreads being widest at the open, narrowing across the morning, stabilizing towards the middle of the day before declining consistently in the afternoon to be narrowest at the close of trade. Regression results documented in Table 1 indicate that spreads in the first four 30-minute intervals for 90 Day BAB futures and first six 30-minute intervals for 3-Year and 10-Year bond futures are significantly higher than spreads in the middle of the day, while spreads in the final 30-minute interval are significantly lower than spreads in the middle of the day.

The decline in bid-ask spreads across each of the contracts supports the argument proposed by Chan, Christie and Schultz (1995) and Chan, Chung and Johnson (1995) that spreads narrow in a competitive setting as dealers seek to control their inventory by quoting aggressively and, in the absence of market power (Brock and Kleidon, 1992), do so by narrowing their offered bid-ask spread.

<Insert Figure 1>

<Insert Table 1>

The intraday pattern in quoted depth is documented in Figure 2 for the three interest rate futures. Quoted depth is lowest at the open of trading and increases throughout the morning, declining only around macroeconomic information announcements at 11.30 a.m. Quoted depth remains relatively stable from midday until mid-afternoon, after which it increases monotonically to the close of trading. For both 3-

Year and 10-Year bond futures, depth increases from approximately -0.67 and -0.24 standard deviates below the mean, respectively, at 1.30 p.m. to 2.84 and 2.79 standard deviates above the mean, respectively, at the close of trade. Quoted depth in 90 Day BAB futures increases monotonically from 0.11 standard deviates above the mean at 2.30 p.m. to 2.04 standard deviates above the mean by the close of trade. Regression results in Table 2 indicate that depth in the final three 30-minute intervals for 90 Day BAB futures and 10-Year bond futures, and the final four 30-minute intervals for 3-Year bond futures, is significantly higher than depth in the middle of the day. This pattern in quoted depth contrasts with the pattern documented by Lee et al. (1993) for specialist markets. For each contract, this intraday pattern supports the hypothesis that competitive dealers manage their inventory by increasing quoted depth as uncertainty is resolved over the trading day, resulting in increasing quoted depth towards the close.[8]

<Insert Figure 2>

<Insert Table 2>

Harris (1994) develops a model identifying volume and volatility as key variables explaining changes in depth, similar to McInish and Wood's (1992) determinants of bid-ask spread study. Table 3 and Figure 3 document intraday patterns in standardized volume for each of the three interest rate futures contracts. The intraday pattern in volume is similar across all four contracts, with volume significantly higher (than volume in the

[8] The intraday behaviour of bid-ask spreads and quoted depth is also examined on a minute-by-minute basis. The results of this are qualitatively similar to the results presented in this paper, and are available upon request.

middle of the day) at the open and close of trading, and elevating around the arrival of macroeconomic information announcements. The pattern in volume is consistent with the intraday pattern previously documented by Frino, Stevenson and Duffy (1998) for the same interest rate futures contracts, and is consistent with prior research documenting U-shaped intraday patterns in both equity and derivative markets.

<Insert Figure 3>

<Insert Table 3>

Table 4 and Figure 4 document intraday patterns in volatility for the three interest rate futures contracts. Price volatility is significantly higher in the first 30-minute interval, consistent with the contention that information asymmetry is highest at the open of trade (Foster and Viswanathan, 1994). There is a significant increase in volatility at 11.30 a.m., coinciding with macroeconomic information announcements. Volatility then increases throughout the remainder of the trading session (relative to volatility in the middle of the day), reaching levels above the mean at the close for all three contracts. Differences in patterns of the determinants of bid-ask spreads and depth cannot therefore explain differences in patterns in bid-ask spreads and depth between competitive dealer and specialist markets.

<Insert Figure 4>

<Insert Table 4>

5. Conclusion

This paper examines the intraday pattern in quoted depth for a competitive dealer market. Several studies argue that as trading resolves uncertainty over the day, competition among dealers seeking to manage their inventory results in a decrease in quoted bid-ask spreads towards the close of trade. Using similar arguments, we predict that quoted depth will increase towards the close of trade. Consistent with these predictions, quoted depth is shown to increase over the day, and this increase is most pronounced in the final hours of trading. Similar to previous studies based on competitive dealer markets, quoted bid-ask spreads narrow towards the close, consistent with the hypothesis that dealers quote aggressively using both increases in quoted depth and tightening bid-ask spreads.

Patterns in determinants of spreads and depth (specifically volume and volatility) are similar to patterns documented in previous research for both specialist and competitive dealer markets. We conclude that the intraday patterns in depth documented in this study are driven by dealers managing their inventory towards the close of trade. Future research could investigate depth across the trading day for other competitive dealer markets (Nasdaq, CBOE) to test if dealer competition is driving the intraday patterns documented. In addition, comparing intraday patterns of liquidity across competitive dealer and pure order driven markets is of interest given the changing structure of international derivatives markets.

Appendix

The Sydney Futures Exchange (SFE) is the largest futures exchange in the Asia-Pacific Region and is ranked among the top 10 financial futures and options exchanges around the world by value of turnover.[9] Trading on the SFE is fully automated through the computerised trading system, SYCOM IV (herein SYCOM). SYCOM is an open electronic limit order book where orders are entered electronically and trading takes place based on price and time precedence rules. Participants can view the three best bid and ask quotes and aggregate order volume at each of these quotes for each interest rate futures contract. Trading is anonymous as broker mnemonics are not visible.

Over the sample period examined in this study, day session trading hours are between 8.30 a.m. and 4.30 p.m. for 90-Day Bank Accepted Bill futures, 3-Year Bond futures and 10-Year Bond futures. All three contracts examined follow a March, June, September and December expiration cycle. 90-day BAB's have a minimum tick of 0.01 yield points (face value of AUD 1,000,000), while 3-Year and 10-Year bond futures each have face values of AUD 100,000 and minimum ticks of 0.01 and 0.005 yield points, respectively.

All prices are quoted on a "100 – yield" basis. This method of quotation differs from US convention, and results in a variable tick *dollar value* based on the level of interest rates. At current interest rate levels (yield of 5.5 percent), the minimum tick size translates into approximately AUD 24 per contract for 90 day BAB's, AUD 28 per contract for 3-Year bonds and AUD 40 per contract for 10-Year bonds.

[9] Frino and Jarnecic (2005).

There are two main types of traders on the SFE: Full Participants and Local Participants, with both having direct access to SYCOM. Full participants conduct business on behalf of clients and/or on their own account. Local Participants ('locals') trade exclusively on their own account, and similar to dealers on the CBOE and Nasdaq, compete against each other for order flow in the provision of liquidity (see Chan, Christie and Schultz, 1995 and Chan, Chung and Johnson, 1995). During 2004, trading by SFE locals accounted for 39.63 percent of total futures volume across the three interest rate contracts.[10] Given the substantial contribution locals make to total volumes, and their role as liquidity providers, the SFE can be categorized as a competitive dealer market similar to Nasdaq and the CBOE. At the time of writing, there were 23 Full Participants and 50 Local Participants operating on the exchange.

[10] SFE 2004 Yearbook.

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Table 1
Estimates of the Intraday Variation in Standardized Bid-Ask Spread

This table reports coefficient estimates of the following model:

$$st(BAS_t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k D_k + \varepsilon_t$$

Where $st(BAS_t)$ is the standardized quoted bid-ask spread in interval t and D_k is a time-of-day dummy variable equal to one if observation t falls in interval k, zero otherwise. For interest rate futures, the interval 12:30 p.m. – 1:00 p.m. is excluded. The significance of each interval relative to the 12:30 p.m. – 1:00 p.m. interval is calculated using a t-statistic derived from OLS estimation of the regression model above. t-statistics are adjusted for heteroskedasticity and autocorrelation using the method of Newey and West (1994), and critical t-values undergo a large sample size adjustment following Johnstone (2005).

Panel A	90 Day BAB		3 Year Bonds		10 Year Bonds	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
8:30:00 - 8:59:59	0.22382	22.97*	0.20542	21.17*	0.41376	43.04*
9:00:00 - 9:29:59	0.19881	20.41*	0.20491	21.12*	0.40162	41.78*
9:30:00 - 9:59:59	0.20527	20.99*	0.21565	22.19*	0.40370	41.94*
10:00:00 - 10:29:59	0.12742	13.22*	0.16160	16.81*	0.23814	25.02*
10:30:00 - 10:59:59	0.03957	4.11	0.08715	9.08*	0.17148	18.03*
11:00:00 - 11:29:59	0.02463	2.59	0.12870	13.52*	0.07573	8.03*
11:30:00 - 11:59:59	-0.00477	-0.50	0.02700	2.84	0.03512	3.73
12:00:00 - 12:29:59	0.01028	1.08	0.00046	0.05	-0.01839	-1.95
12:30:00 - 12:59:59						
13:00:00 - 13:29:59	-0.00293	-0.31	0.02511	2.64	0.00355	0.38
13:30:00 - 13:59:59	0.00621	0.65	0.02333	2.45	-0.00293	-0.31
14:00:00 - 14:29:59	0.01009	1.06	0.01086	1.14	0.00370	0.39
14:30:00 - 14:59:59	-0.00069	-0.07	0.00334	0.35	-0.00530	-0.56
15:00:00 - 15:29:59	-0.01876	-1.97	-0.00229	-0.24	-0.01025	-1.09
15:30:00 - 15:59:59	-0.02267	-2.39	-0.01100	-1.16	-0.02695	-2.86
16:00:00 - 16:30:00	-0.03476	-5.36*	-0.01831	-1.94	-0.04617	-5.95*

*Indicates significance at the 0.001 level

Table 2
Estimates of the Intraday Variation in Standardized Depth

This table reports coefficient estimates of the following model:

$$st(depth_t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k D_k + \varepsilon_t$$

Where $st(depth_t)$ is the standardized quoted depth occurring in interval t and D_k is a time-of-day dummy variable equal to one if observation t falls in interval k, zero otherwise. For interest rate futures, the interval 12:30 p.m. – 1:00 p.m. is excluded. The significance of each interval relative to the 12:30 p.m. – 1:00 p.m. interval is calculated using a t-statistic derived from OLS estimation of the regression model above. t-statistics are adjusted for heteroskedasticity and autocorrelation using the method of Newey and West (1994), and critical t-values undergo a large sample size adjustment following Johnstone (2005).

Panel A	90 Day BAB		3 Year Bonds		10 Year Bonds	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
8:30:00 - 8:59:59	-0.26065	-26.79*	-0.03032	-5.40*	-0.11725	-12.18*
9:00:00 - 9:29:59	-0.16231	-16.68*	-0.02616	-3.76	-0.10341	-10.74*
9:30:00 - 9:59:59	-0.12248	-12.54*	-0.02354	-3.48	-0.09928	-10.30*
10:00:00 – 10:29:59	0.00858	0.89	0.07701	7.20*	-0.02449	-2.57
10:30:00 – 10:59:59	0.04076	4.24	0.07849	7.38*	0.01571	1.65
11:00:00 – 11:29:59	0.02888	3.04	0.05448	4.86	0.06181	6.55*
11:30:00 – 11:59:59	-0.01223	-1.29	0.05584	5.02	0.01963	2.08
12:00:00 – 12:29:59	0.02593	2.73	0.06790	5.12	0.04629	4.91
12:30:00 – 12:59:59						
13:00:00 – 13:29:59	-0.00961	-1.01	-0.04553	-4.91	-0.02791	-2.96
13:30:00 – 13:59:59	-0.01107	-1.17	-0.02908	-3.13	-0.01847	-1.96
14:00:00 – 14:29:59	0.00304	0.36	0.04186	4.51	0.01276	1.35
14:30:00 – 14:59:59	0.00711	0.75	0.14833	15.99*	0.04598	4.88
15:00:00 – 15:29:59	0.05311	5.59*	0.30207	32.57*	0.08001	8.49*
15:30:00 – 15:59:59	0.10723	11.30*	0.50070	53.98*	0.17393	18.46*
16:00:00 – 16:30:00	0.17751	18.85*	0.83013	90.23*	0.55117	58.96*

*Indicates significance at the 0.001 level

Table 3
Estimates of the Intraday Variation in Standardized Volume

This table reports coefficient estimates of the following model:

$$st(volume_t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k D_k + \varepsilon_t$$

Where $st(volume_t)$ is the standardized volume in interval t and D_k is a time-of-day dummy variable equal to one if observation t falls in interval k, zero otherwise. For interest rate futures, the interval 12:30 p.m. – 1:00 p.m. is excluded. The significance of each interval relative to the 12:30 p.m. – 1:00 p.m. interval is calculated using a t-statistic derived from OLS estimation of the regression model above. t-statistics are adjusted for heteroskedasticity and autocorrelation using the method of Newey and West (1994), and critical t-values undergo a large sample size adjustment following Johnstone (2005).

Panel A	90 Day BAB		3 Year Bonds		10 Year Bonds	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
8:30:00 - 8:59:59	0.22523	23.10*	0.57973	60.24*	0.33946	35.09*
9:00:00 - 9:29:59	0.06419	6.58*	0.18753	19.49*	0.09419	9.74*
9:30:00 - 9:59:59	0.08306	8.48*	0.17450	18.11*	0.09342	9.64*
10:00:00 - 10:29:59	0.14083	14.60*	0.17054	17.88*	0.16760	17.50*
10:30:00 - 10:59:59	0.06180	6.41*	0.08790	9.23*	0.05809	6.07*
11:00:00 - 11:29:59	0.11620	12.19*	0.13195	13.98*	0.15255	16.08*
11:30:00 - 11:59:59	0.17562	18.46*	0.30016	31.86*	0.13169	13.91*
12:00:00 - 12:29:59	0.04674	4.91	0.08015	8.51*	0.05636	5.95*
12:30:00 - 12:59:59						
13:00:00 - 13:29:59	-0.01946	-2.04	-0.02392	-2.54	-0.02462	-2.60
13:30:00 - 13:59:59	-0.00179	-0.19	-0.01539	-1.63	-0.01046	-1.10
14:00:00 - 14:29:59	0.02183	2.29	0.02018	2.14	0.01027	1.08
14:30:00 - 14:59:59	0.05009	5.26	0.06976	7.40*	0.05289	5.58*
15:00:00 - 15:29:59	0.05369	5.64*	0.08642	9.17*	0.07070	7.46*
15:30:00 - 15:59:59	0.08599	9.04*	0.15372	16.31*	0.13100	13.83*
16:00:00 - 16:30:00	0.21612	22.90*	0.37491	40.11*	0.39938	42.51*

*Indicates significance at the 0.001 level

Table 4
Estimates of the Intraday Variation in Standardized Volatility

This table reports coefficient estimates of the following model:

$$st(volatility_t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k D_k + \varepsilon_t$$

Where $st(volatility_t)$ is the standardized volatility in interval t and D_k is a time-of-day dummy variable equal to one if observation t falls in interval k, zero otherwise. For interest rate futures, the interval 12:30 p.m. – 1:00 p.m. is excluded. The significance of each interval relative to the 12:30 p.m. – 1:00 p.m. interval is calculated using a t-statistic derived from OLS estimation of the regression model above. t-statistics are adjusted for heteroskedasticity and autocorrelation using the method of Newey and West (1994), and critical t-values undergo a large sample size adjustment following Johnstone (2005).

Panel A	90 Day BAB		3 Year Bonds		10 Year Bonds	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
8:30:00 - 8:59:59	0.33826	34.73*	0.49748	51.58*	0.59393	61.70*
9:00:00 - 9:29:59	0.12126	12.45*	0.21802	22.61*	0.18904	19.64*
9:30:00 - 9:59:59	0.09801	10.02*	0.14221	14.73*	0.14432	14.97*
10:00:00 - 10:29:59	0.11726	12.17*	0.16504	17.27*	0.20806	21.83*
10:30:00 - 10:59:59	0.06113	6.35*	0.07120	7.46*	0.08669	9.10*
11:00:00 - 11:29:59	0.12016	12.62*	0.18118	19.16*	0.20224	21.42*
11:30:00 - 11:59:59	0.16930	17.82*	0.29955	31.73*	0.29269	31.06*
12:00:00 - 12:29:59	0.05303	5.58*	0.11420	12.10*	0.11036	11.71*
12:30:00 - 12:59:59						
13:00:00 - 13:29:59	-0.02320	-2.44	-0.03549	-3.76	-0.03643	-3.87
13:30:00 - 13:59:59	-0.01949	-2.05	-0.02540	-2.69	-0.03222	-3.42
14:00:00 - 14:29:59	0.01283	1.35	0.00780	0.83	0.01998	2.12
14:30:00 - 14:59:59	0.03594	3.78	0.05772	6.11*	0.07035	7.46*
15:00:00 - 15:29:59	0.04411	4.64	0.10240	10.84*	0.09883	10.49*
15:30:00 - 15:59:59	0.07715	8.12*	0.17894	18.95*	0.17850	18.94*
16:00:00 - 16:30:00	0.18704	19.84*	0.33057	35.29*	0.31610	33.81*

*Indicates significance at the 0.001 level

Figure 1
Intraday Variation in Standardized Bid-Ask Spreads

This figure depicts intraday patterns in standardized bid-ask spreads for 90 Day BAB, 3 Year Bond and 10 Year Bond futures in 30-minute intervals. The sample extends from 1 February, 2001 to 31 December, 2004. Bid-ask spreads are measured as the ask quote minus the bid quote divided by the minimum tick for each contract across one minute intervals and then averaged across 16 equal 30-minute intervals. The bid-ask spread is standardized by subtracting the daily mean and dividing by the daily standard deviation for each series.

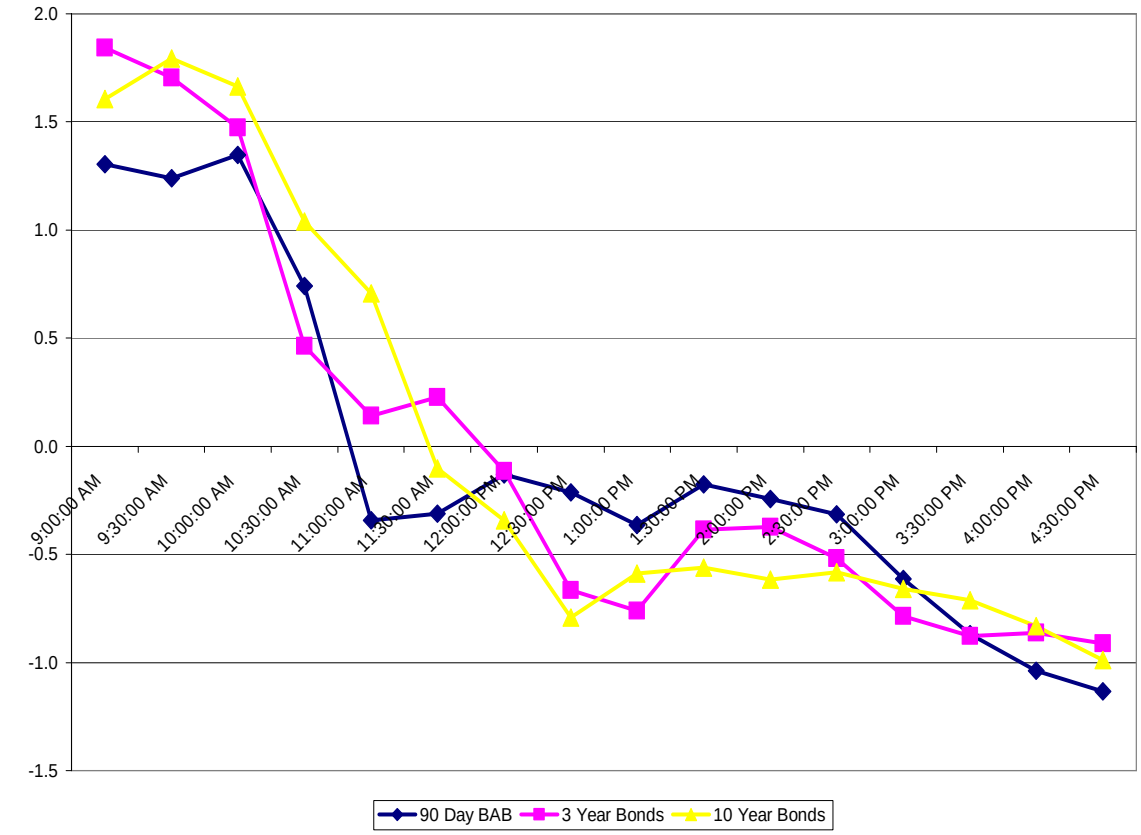

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Figure 2
Intraday Variation in Standardized Quoted Depth

This figure depicts intraday patterns in standardized depth for 90 Day BAB, 3 Year Bond and 10 Year Bond futures in 30-minute intervals. The sample extends from 1 February, 2001 to 31 December, 2004. Quoted depth is measured as the average of the volume available at the best bid and best ask quotes at the end of each one minute interval and then averaged across 16 equal 30-minute intervals. Depth is standardized by subtracting the daily mean and dividing by the daily standard deviation for each series.

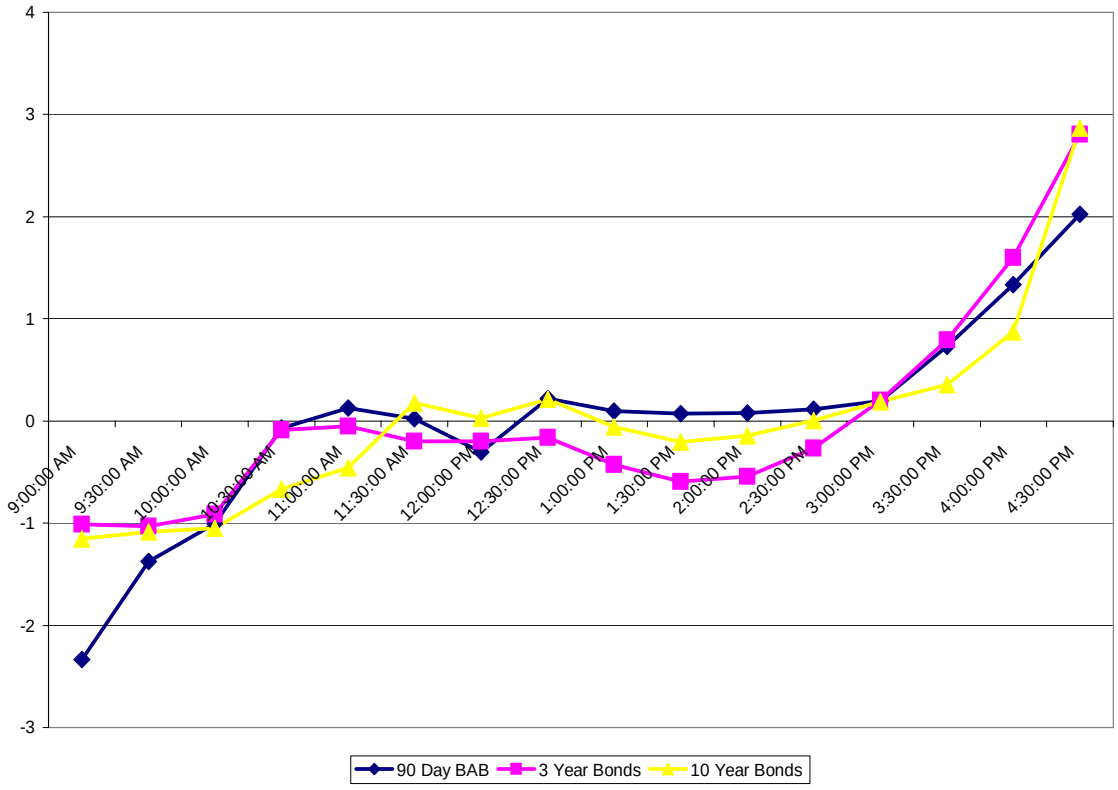

Figure 3
Intraday Variation in Standardized Trading Volume

This figure depicts intraday patterns in standardized volume for 90 Day BAB, 3 Year Bond and 10 Year Bond futures in 30-minute intervals. The sample extends from 1 February, 2001 to 31 December, 2004. Traded volume is measured as the number of contracts traded across each 30-minute interval. Volume is standardized by subtracting the daily mean and dividing by the daily standard deviation for each series.

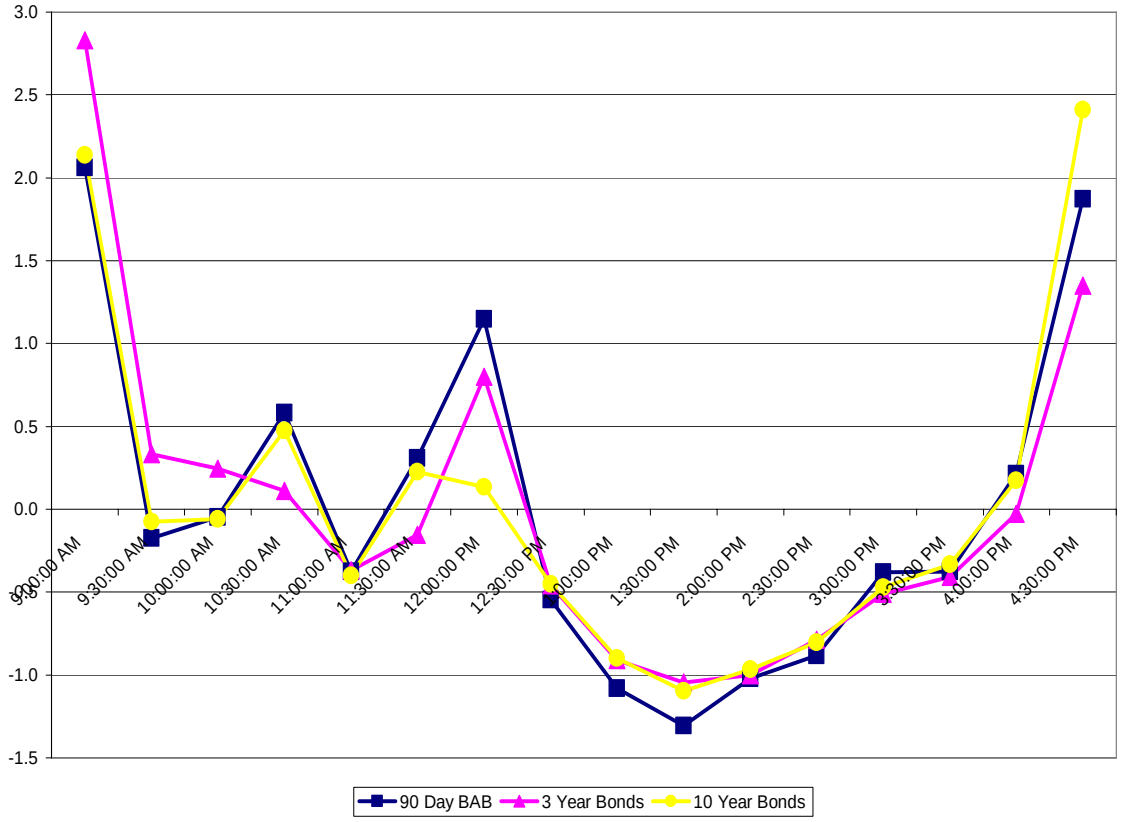

Figure 4
Intraday Variation in Standardized Volatility

This figure depicts intraday patterns in standardized volatility for 90 Day BAB, 3 Year Bond and 10 Year Bond futures in 30-minute intervals. The sample extends from 1 February, 2001 to 31 December, 2004. Volatility is measured as the absolute value of the price change across successive 30-minute intervals for interest rate contracts. Volatility is standardized by subtracting the daily mean and dividing by the daily standard deviation for each series.