Intranight Trading on The Sydney Futures Exchange

ALEX FRINO, ANDREW LEPONE and GRANT WEARIN*

Finance Discipline, School of Business, Faculty of Economics and Business,

University of Sydney, NSW, 2006, Australia

*Corresponding Author: Finance Discipline, School of Business, University of Sydney, 2006, Australia: Tel (612) 9256 0439; Fax (612) 9256 0144; Email: g.wearin@econ.usyd.edu.au

This research was funded by the Sydney Futures Exchange under Corporations Regulation 7.5.88(2). The authors thank the Securities Industry Research Centre of Asia-Pacific (SIRCA) for the provision of data and the comments of seminar participants at the University of Sydney and the Business Development Division of the Sydney Futures Exchange.

Abstract

This paper examines "intranight" patterns in quoted bid-ask spreads and depth, price volatility and trading volume in the SPI200, 90 Day BAB, 3 Year Bond and 10 Year Bond futures contracts traded on the Sydney Futures Exchange (SFE). Across all contracts, we document an elevation in both price volatility and trading volume at the open and close of overnight trading sessions, consistent with prior literature examining daytime markets and an elevation in both volume and volatility surrounding the opening of US futures and equity markets and the arrival of US macroeconomic information announcements. In contrast to prior research, we document an upside down U-shaped pattern in quoted bid-ask spreads, with spreads narrowest at the open and close of the intranight session. Quoted depth follows a U-shaped pattern, where depth is deepest at the open and close of the intranight session. Further tests indicate that the intranight pattern in the bid ask spread and quoted depth can be largely explained by variables typically used in cross-sectional models of the bid ask spread, changes in the trading population, the opening of the US markets and US announcements and variables that proxy for the evolution of pricing risk throughout the night.

1. Introduction

A large volume of securities market research has examined intraday patterns in volume, volatility, bid-ask spreads and, to a lesser extent, quoted depth.[1] The findings of this research have formed the basis of subsequent inquiry into securities market behaviour centred around issues such as information assimilation, and the influence of different market designs on the cost of trading.[2] Despite its significance, the analysis of patterns in liquidity has not yet been extended to overnight trading sessions. This paper provides the first analysis of 'intranight' trading behaviour.[3] It documents and analyses four important dimensions of trading behaviour, namely quoted bid-ask spreads, quoted depth, price volatility and trading activity.

Both Nasdaq and the Chicago Stock Exchange (CHX) introduced extended trading hour sessions on their electronic systems during 1999.[4] The CBOE also launched an electronic trading system, CBOEdirect, in June 2001 to facilitate extended trading hour sessions.[5] In addition, the NYSE has proposed the introduction of overnight trading sessions to complement daytime trading.[6] The move towards overnight trading is in response to competition from electronic exchanges offering after-hours trading, as well as pressure from a broader group of stockowners existing

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[1] For intraday patterns see Wood, McInish and Ord (1985); Mcinish and Wood (1990a, 1990b); Mcinish and Wood (1992) who all document similar intraday patterns in volume and volatility on the NYSE; and Chan et al (1995a); Chan et al (1995b) who document intraday patterns for competitive market structures.

[2] Ederington and Lee, 1993, 1995 look at the speed of information assimilation, and Chan et al., 1995a look at the influence of market structure.

[3] Previous literature has examined trading behaviour on Globex (e.g. Chow et al., 1996; Coppejans and Domowitz, 1996) and APT (Gwilym and Thomas, 1998), however these papers compare electronic and floor trading rather than the patterns in overnight trading. Huang and Masulis (1999) document the behaviour in over-the-counter foreign-exchange bid-ask spreads over the 24-hour trading day.

[4] See "Nasdaq to begin after hours operation of trade reporting and quotation systems on Monday October 25", Nasdaq-Amex Press Release, 22 October 1999 and "Light CHX E-session volume in line with expectations", CHX Press Release, 29 October 1999.

[5] See "CBOE to launch CBOEdirect screen-based trading system June 1, 2001", CBOE Press Release, 1 March 2001.

today, many of whom prefer to trade outside traditional trading hours.[7] Several of the world's most prominent futures exchanges currently operate overnight electronic trading systems, including the Chicago Mercantile Exchange (Globex), Chicago Board of Trade (a/c/e), New York Mercantile Exchange (ACCESS), London International Financial Futures and Options Exchange (LIFFE CONNECT), MATIF (Globex) and Sydney Futures Exchange (SYCOM). While the overnight trading sessions in Europe and North America are relatively short and thinly traded (relative to daily volumes), trading on SYCOM is sufficiently liquid to allow a meaningful analysis of intranight trading behaviour.[8]

In this paper we focus on the four most liquid contracts trading on the SFE – the SPI200, 90 Day BAB, 3 and 10 Year Bond futures contracts. We find an elevation in both price volatility and trading volume at the open and close of overnight trading sessions, consistent with prior literature examining daytime markets. We also report a sharp increase in volatility and volume around the opening of the US markets. In contrast to prior research examining *intraday* patterns, quoted bid-ask spreads follow an inverted U-shaped pattern while quoted depth follows a U-shaped pattern across the intranight session. Further analysis shows that the patterns in the bid-ask spread and quoted depth can be largely explained by intra-night variation in volume and volatility, the trading activity of Australian local traders, and variables that proxy for the evolution of pricing risk throughout the night.

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[6] Refer "Big board sees only limited demand for night trading, but feels compelled", The Wall Street Journal, 25 May 1999.
[7] Approximately 50% of America's households now own stocks with many preferring to trade outside traditional trading hours. Refer "Trading into the night", Chicago Tribune, 25 May 1999.
[8] For example, in 2005, overnight trading volume on SYCOM represented 23% of total exchange volume.

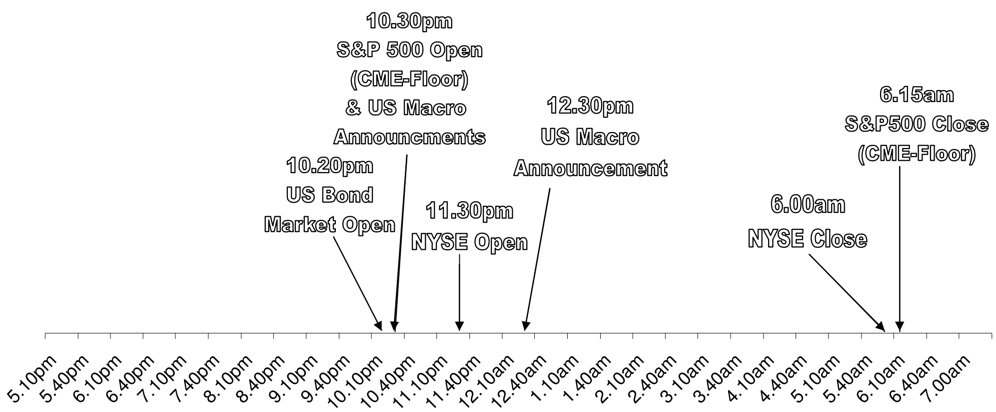
The remainder of this paper is structured as follows. Section 2 documents relevant institutional detail for the Sydney Futures Exchange and discusses the data used in this study. Section 3 develops some theoretical predictions on intranight trading behaviour. Section 4 describes the methodology and presents the results, and Section 5 concludes.

2. Institutional Detail, Data and Method

SYCOM was launched on 30 November 1989 and was the first electronic overnight trading system to be installed in the world. For the sample period examined in this study, 1 January 2002 to 31 December 2005, futures were traded over SYCOM IV, the SFE's electronic trading platform daytime. Daytime trading commenced at 09:50 and stopped at 16:30 for the SPI200 and 08:30 and 16:30 for interest rate futures. Overnight trading hours on SYCOM are from 17:10 to 07:00 during US Daylight saving time and from 17:10 to 08:00 during US non-daylight saving for the SPI200.[9] Overnight trading in interest rate futures commences at 17:10 and closes at 07:00 during US Daylight saving time or 07:30 during US non-daylight saving time. Figure 1 illustrates US events occurring during overnight SYCOM trading hours and the time in US financial centres during AEST.

[9] Sydney operates on daylight saving time (AEDT) from the last Sunday in October until the last Sunday in March, changing the time difference between Sydney and the US. The US operates on daylight saving time from the first Sunday in April until the last Sunday in October.

Figure 1. Timeline of US Events (US Daylight saving time) in Australian Eastern Standard Time.



SYCOM is an electronic limit order book where both Local SFE Participants and Full SFE Participants enter orders directly into the SYCOM order book. A pre-opening phase precedes open trading where individual orders can be submitted into the limit order book and executed at the commencement of open trading based on an algorithm which determines a 'common price' that maximises the number of executable trades. Limit orders placed on SYCOM that do not immediately execute are queued and executed on a price and time priority basis. By the end of the sample period SYCOM revealed price and quantity at the first five price and depth levels on the bid and ask for the SPI200 and 10 year bond futures contract and the first three price and depth steps for 90 Day BAB and 3 year bond futures contracts. When a trade is executed, all traders are able to view, in real-time, the traded volume and price of the trade but not the identity of the brokers that executed the trade.

Most studies of intraday trading patterns in volume, volatility and bid ask spreads have focused on individual stocks, stock options or stock index futures (McInish and Wood (1992), Ekman(1992), Sheikh and Ronn (1994)). We focus on both the SPI200 contract which is the major stock index futures contract traded on the SFE, and the three most liquid interest rate products. Together these interest rate contracts cover the short and long end of the interest rate yield curve.

The SPI200 is written over the S&P/ASX200 Index, the constituent stocks of which are traded on the Australian Stock Exchange (ASX). The S&P/ASX200 Index is based on the share prices of the top 200 listed companies, weighted according to the market capitalisation of those companies. The 90 Day BAB contract is written over $1 million in face value of Banker's Acceptances or Electronic Bills of Exchange with a maturity of between 85-95 days. The 3 and 10 year bond futures are written over Commonwealth Government Treasury Bonds with a face value of $100,000, a coupon rate of 6% per annum and a maturity of 3 years (for 3 year bond futures) or 10 years (for 10 year bond futures).

Data was sourced from the Reuters database at SIRCA and extends from 1 January 2002 to 31 December 2005. It provides minute by minute snapshots of the market detailing the price of the last trade to occur in the minute, prevailing best bid ask quotes and quoted depth at the end of each minute, cumulated traded volume and the number of trades over the minute. SYCOM data is disseminated by SFE to data vendors such as Reuters and Bloomberg who enable their customers to view the same content of the limit order book as traders on SYCOM. Consistent with prior event studies in futures markets, we confine our analysis to daytime trading in the near term contract.[10] Raw data for this study examines the period when Sydney is operating on AEDT *and* the USA is operating on Eastern Standard Time (EST). For trading outside these times, appropriate time adjustments are made to the data such that the intranight pattern does not shift.

The bid-ask spread is measured as the ask price minus the bid price at the end of each minute, *t*. 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.

$$Volatility_t = | price_t - price_{t-1} | \qquad \{2\}$$

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.

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

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 robustness of intranight patterns in quoted depth, bid-ask spreads, volume and volatility, standardised variables are regressed on a set of

[10] See Frino et al. (2001).

intranight variables. For example, 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 standardised 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, otherwise equal to zero. The regression equation is then repeated for bid-ask spreads, volume and volatility. The half hour interval **xx:30:00am – yy:00:00am** is excluded in constructing time-of-night dummy variables for the interest rate contracts and the 30 minute interval **1:10:00pm – 1:40:00pm** for the SPI200. T-statistics are adjusted for heteroskedasticity and autocorrelation using the procedure described in Newey and West (1994) in addition to a large sample size adjustment for the critical t value, outlined in Johnstone (2005).

3. Hypothesis Development

Several factors are likely to influence intranight trading behaviour on SYCOM. In addition to variables typically used in microstructure studies, we focus on spill-over effects from related markets, changes in the population of market participants and the evolution of pricing risk throughout the night.

King and Wadhwani (1990) develop a contagion model that shows how traders in one market draw information from observed price movements in related markets. Chang et al. (1995) test one of the implications of the model - that price volatility will be elevated when a related market is open and lower when it is closed. They provide evidence consistent with this prediction by examining the price behaviour of the CME's S&P 500 stock index futures around the open and close of the NYSE.

Other literature has found that price movements in Asia-Pacific financial markets are related to those in US markets. For example, Copeland and Copeland (1998) conclude that "the Americas lead Europe and the Pacific by one day, presumably because the driving information is generated in the Americas" (p.76). Hence it is likely that Australian financial markets draw information from trading in US markets and the contagion model implies that price volatility in US and Australian markets are related. Given that US markets open during the overnight trading session on SYCOM, it is expected volatility is higher when the US markets are open. Furthermore, we expect that the well-documented elevation in volatility at the open of US markets (e.g. Wood et al., 1985; Ekman, 1992) will spill over to SYCOM at that time.

Prior research has documented an elevation in price volatility and trading volume at the open and close of daytime trading sessions (e.g. Wood, McInish and Ord, 1985, Harvey and Huang, 1991, and Webb and Smith, 1994). The elevation in price volatility and trading volume has been attributed to strategic trading by informed traders (Admati and Pfleiderer, 1988; Foster and Viswanathan, 1994), and opening procedures (Amihud and Mendelson, 1987). Wider bid-ask spreads at the open have also been attributed to price uncertainty that is resolved during the course of the trading day (Madhavan, 1992), and market power of market makers (Brock and Kleidon, 1992). Bid-ask spreads in competitive dealer markets (including futures markets) have been found to be elevated at the open and to narrow as the trading session progresses (Frino and Wearin, 2005; McInish and Wood, 1992; Chan et al., 1995a, 1995b). Based on the previous literature, it is expected that price volatility and trading volume during overnight trading are elevated at the open and close of trading, and bid-ask spreads narrow throughout the trading session. We also expect to see a more permanent increase in volume and volatility around and following the opening of US markets because of spill-over effects.

A complicating factor in analysing overnight trading on the SFE is the changes in the location and composition of the trading population. With the opening of the US market, there is an inflow of demanders and providers of liquidity from the US. At the same time, we expect a gradual decrease in the number of Australian locals throughout the night, simply because it is costly for locals to work during the night. Furthermore, Australian locals are expected to be lower cost liquidity providers relative to US-based liquidity providers. Firstly, Australian locals have a slight, but potentially important, advantage in terms of response time in the trading system, reducing their exposure to being picked off (Berkman, 1996). Secondly, all local full participant firms that are active during the night are active during daytime and face relatively low costs laying off unwanted inventory built up during the night. Consequently, we expect the spread to be lower when Australian locals are relatively more active (see also Huang and Masulis, 1999).

Finally, given that the underlying asset markets are closed during the overnight trading session, there is increasing uncertainty with regard to the true price of the underlying asset. Prior literature examining lead-lag relations finds that futures markets generally lead equities markets, but there is also feedback from equities markets to futures markets (see Chan, 1992). We hypothesize that as the most recent signal from the underlying market gets older, its usefulness deteriorates, leading to greater uncertainty as to the 'true' price and hence wider bid-ask spreads. To proxy for this uncertainty, we include the absolute value of the percentage price change in the futures contract since the start of the overnight trading session. We hypothesize that the pricing risk for the futures contract, increases in this (absolute) price change.

Based on the 'commonality' literature (Chordia et al, JFE 200.), we introduce another proxy for the pricing error risk. There might be common factors related to changes in pricing risk throughout the night that are not captured by the variables above. To the extent that these common factors are relevant to, for example, both the bond futures contract and the stock index futures contract, we expect the bid ask spread of the bond futures contract to be related to the bid ask spread of the stock index futures contract. Examples of possible common factors are changes in interest rates affecting carrying costs for market makers, and uncertainty related to new information with regard to the state of the economy.

The discussion in this section implies that there are likely to be systematic patterns in quoted bid-ask spreads, price volatility and trading volume during overnight trading sessions. First, existing strategic trading models imply that price volatility and trading volume are likely to be elevated at the open and close of overnight trading, and volume and volatility are expected to be high after the opening of the US markets. The prediction with regard to the bid ask spread and quoted depth is more ambiguous. Based on the SYCOM market structure we might expect to see a stable bid ask spread during the night, which narrows towards the close of the night session. However, changes in the population of traders and increasing pricing risk throughout the night point to an increasing bid ask spread.

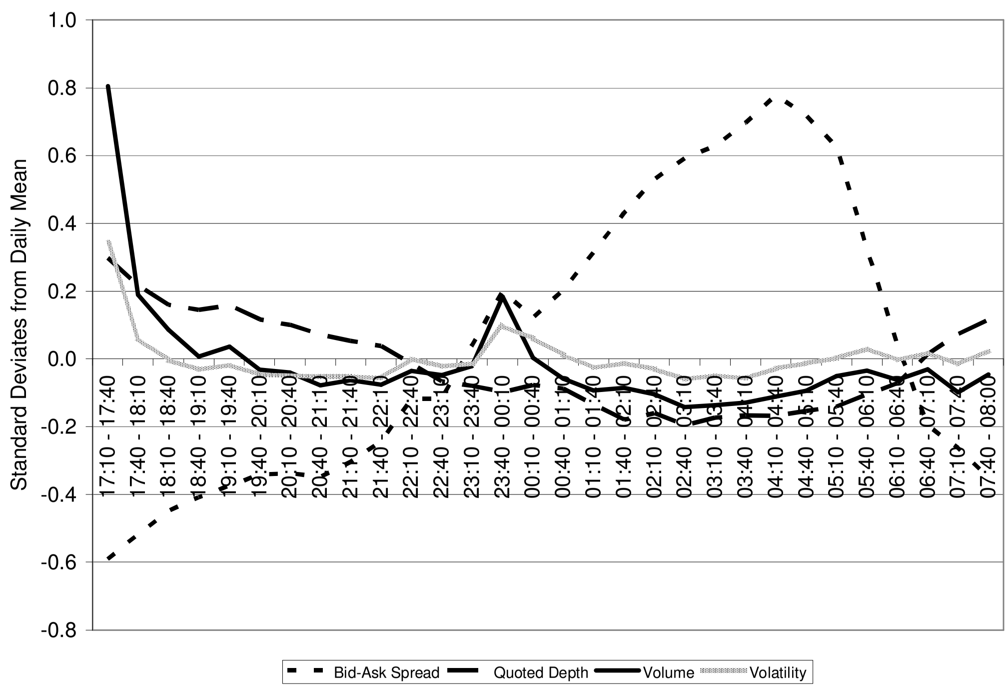
4. Results

4.1 Intranight Patterns in Trading Volume, Price Volatility, Bid-Ask Spreads and Quoted Depth

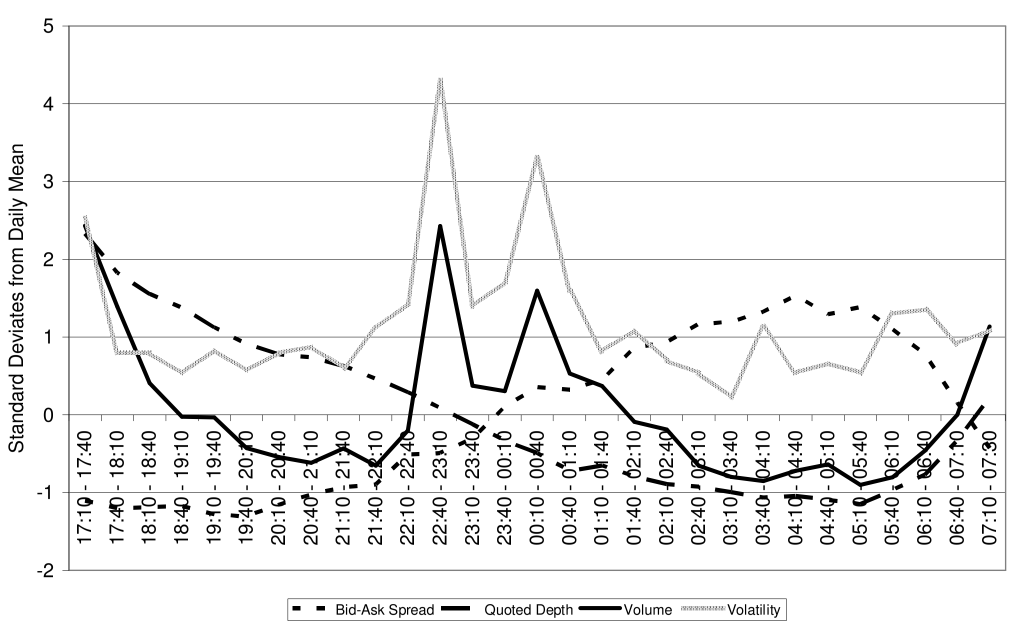
Figure 2 illustrates the intranight patterns in trading volume, price volatility, bid-ask spreads and quoted depth for SPI200, 90 Day BAB, 3 Year Bond and 10 Year bond futures contracts across all trading days. These patterns are similar across the three interest rate contracts. Figure 2 documents an elevation in traded volume and price volatility at the open and close of overnight trading, consistent with intraday patterns previously documented for daytime markets. Upward spikes in volume and volatility also occur around the opening of US bond and futures markets (10:20pm and 10:30pm AEST respectively). Bid-ask spreads are narrow around the open of overnight trading and continue to widen throughout the overnight session, peaking in the 4:10am – 4:40am interval, before narrowing in the final two hours of the session. This pattern is inconsistent with existing theories of the intraday pattern in bid-ask spreads. Bid-ask spreads peak in the half hourly intervals containing US bond and futures market openings and macroeconomic information release times. The intranight pattern in quoted depth mirrors the pattern in bid-ask spreads. Quoted depth is deepest at the open of the overnight market, gradually declining as the session progresses and then increasing in the final two hours of trading. The intranight pattern in trading volume, price volatility, bid-ask spreads and quoted depth for SPI200 futures is similar to those of the interest rate contracts, only on a smaller scale. However, the elevation in volume, volatility and bid-ask spreads is confined to only one time interval coinciding with the opening of the NYSE.

Figure 2. Intranight Patterns in Trading Volume, Price Volatility, Bid-Ask Spreads and Quoted Depth

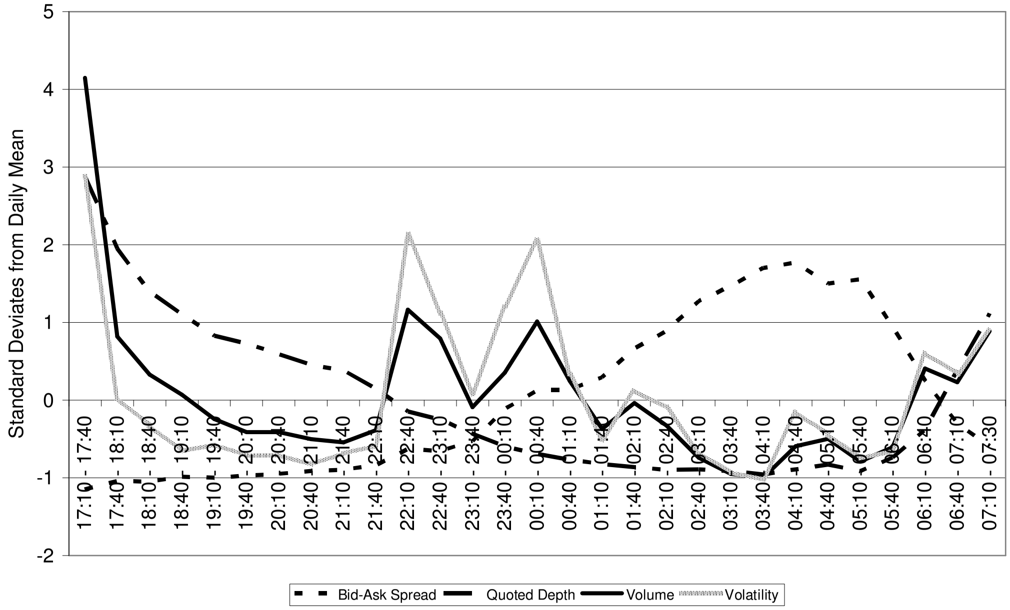
Panel A – SPI200 Futures



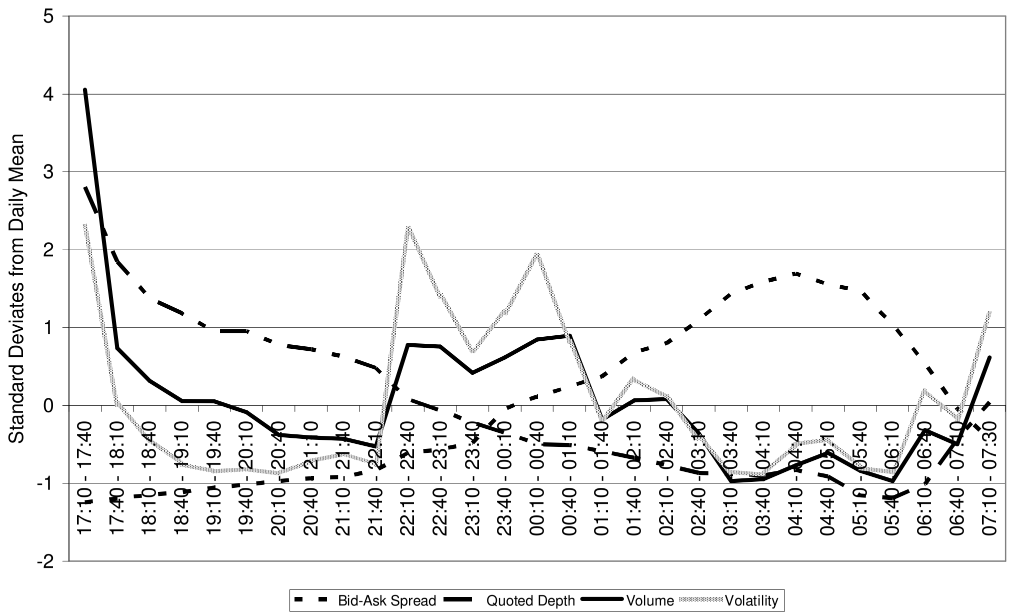
Panel B – 90 Day BAB Futures



Panel C – 3 Year Bond Futures



Panel D – 10 Year Bond Futures



Casual inspection of Figure 2 suggests that the spill-over effect is strongest for interest rate contracts around the opening of US bond markets and the CME whereas the open of the S&P500 Index futures and the NYSE have stronger influence on the SPI200 contract. Given trading volume and volatility remain at a higher level after the opening of the US markets it is clear that market participants in the Australian market draw substantial information from the US markets. Trading in interest rate futures on the CBOT and CME start at 07:20 Chicago time (10:20pm AEST), and trading on the NYSE and S&P 500 stock index futures contract (traded on the CME) starts at 09:30 New York time (11:30pm AEST).

The intranight pattern in quoted bid-ask spreads is strikingly different to that previously documented for daytime trading and is inconsistent with previous theories modelling the bid-ask spread. Bid-ask spreads do not narrow as the trading session progresses, but instead gradually widen during the overnight session. Toward the close of the night-time trading session bid ask spreads begin to fall. Mirroring the pattern in bid-ask spreads, the intranight pattern in quoted depth is also unique and warrants further reconciliation. The following section presents a multivariate regression model of the spread in an attempt to reconcile this pattern.

4.2 Multivariate Model for the Bid-Ask Spread and Quoted Depth

McInish and Wood (1992) find that a significant portion of the intraday variation in bid-ask spreads on the NYSE can be explained by intraday variation of volatility and trading volume. The inventory holding cost and information asymmetry models discussed previously imply that bid-ask spreads widen during periods of high volatility, as dealers require higher compensation for inventory risk and the increased risk of trading with informed traders. Inventory holding cost models also imply that trading volume is negatively related to bid-ask spreads, as higher trading volume allows competing market makers to avoid accumulating excessive inventory.

In addition to contemporaneous volatility and trading volume for each time interval, we include the number of different local traders that traded in each 30-minute period. Given that Australian locals are expected to be the lowest cost providers of liquidity, we expect a negative relation between the bid ask spread and the number of locals in the market. We conjecture that the spread-reducing impact of locals decreases as the number of locals increases. Figure 3 below depicts the average number of locals active in each 15 minunte period averaged across all contracts (averaged across all trading nights).

Figure 3. Intranight Participation by Local Traders

To proxy for the uncertainty with regard to the true price of the SPI200 futures contract, we include the absolute value of the percentage price change in the SPI200 since the inception of the overnight trading session. In addition, the bid ask spread for the 10 Year Bond Futures contract is included as an explanatory variable to proxy for common factors not captured by the other explanatory variables. Furthermore, we include the price of the contract, the time to maturity of the futures contract, and a dummy variable that equals one if there is a US macro-economic announcement at 8.30 (01:30 AEDT), and zero otherwise. Finally, we include day of the week dummies, and time-of-day dummy variables representing each 30-minute interval from 15:10 to 07:30 (15:10 to 08:00 for the SPI200). Each dummy variable indicates the ending time of the 30-minute interval. For example, T2340 refers to the 30 minute period from 23:10 to 23:40. The dummy variable representing the time period ending at 0.30 is excluded. Following McInish and Wood (1992), we take the square root of all the variables to reduce the skewness of these variables. The following models are estimated to model intraday bid-ask spreads and quoted depth. The first model is used for the SPI200 and the following model for all three interest rate futures contracts:[11,12]

$$BAS_t = a_0 + a_1 VOLATILITY_t + a_2 VOLUME_t + a_3 LOCAL + a_4 LOCAL^2 + a_5 \left| \frac{\overline{P}_t}{P_0} \right| + a_6 SPREADS\_BOND_t$$
$$+ a_7 P + a_8 TTM_t + a_{10} D_{US} + \sum_{i=1}^{4} \beta_i D_j + \sum_{ji=1}^{29} \gamma_j D_i + \varepsilon_t$$

$$BAS_t = a_0 + a_1 VOLATILITY_t + a_2 VOLUME_t + a_3 LOCAL + a_4 LOCAL^2 + a_5 \left| \frac{\overline{P}_t}{P_0} \right|_t + a_7 P + a_8 TTM_t$$
$$+ a_{10} D_{US} + \sum_{i=1}^{4} \beta_i D_j + \sum_{ji=1}^{29} \gamma_j D_i + \varepsilon_t$$

Panel A of Figure 4 illustrates the adjusted and unadjusted intranight pattern in the bid-ask spread for the SPI200 and the significance statistics for the multivariate model is presented in Panel A of Table 1. Panels B, C and D present the results for 90 Day BAB, 3 and 10 Year Bonds respectively. Consistent with other analyses of the bid-ask

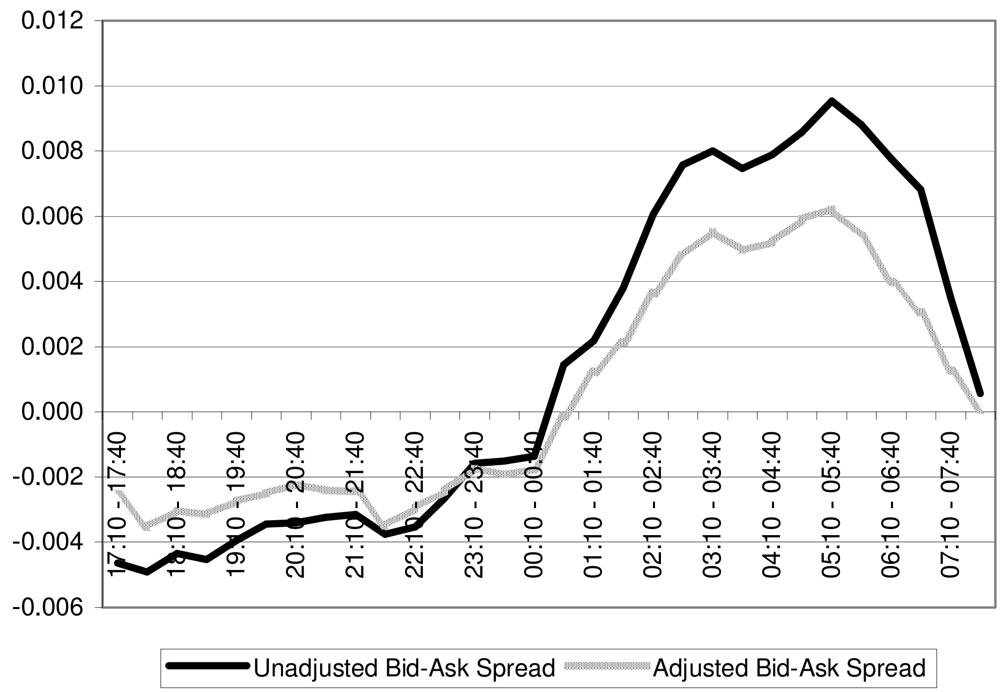
[11] We also interchange the variable dependent "BAS" with "QUOTED_DEPTH" and re-run the model to test the multivariate model on quoted depth.
[12] The variable "SPREADS_BOND", based on the commonality literature, is removed when fitting the model for the three bond futures contracts.

spread we find that volatility is positively related to the bid-ask spread, and price and trading volume are negatively related to the bid ask spread (see for example, McInish and Wood 1992). The three variables are highly significant. The number of locals is negatively related to the bid ask spread, supporting our contention that Australian locals are relatively low cost suppliers of liquidity. The positive coefficient on the squared number of locals variable indicates that the reduction in the bid-ask spread decreases as the number of locals' increases.

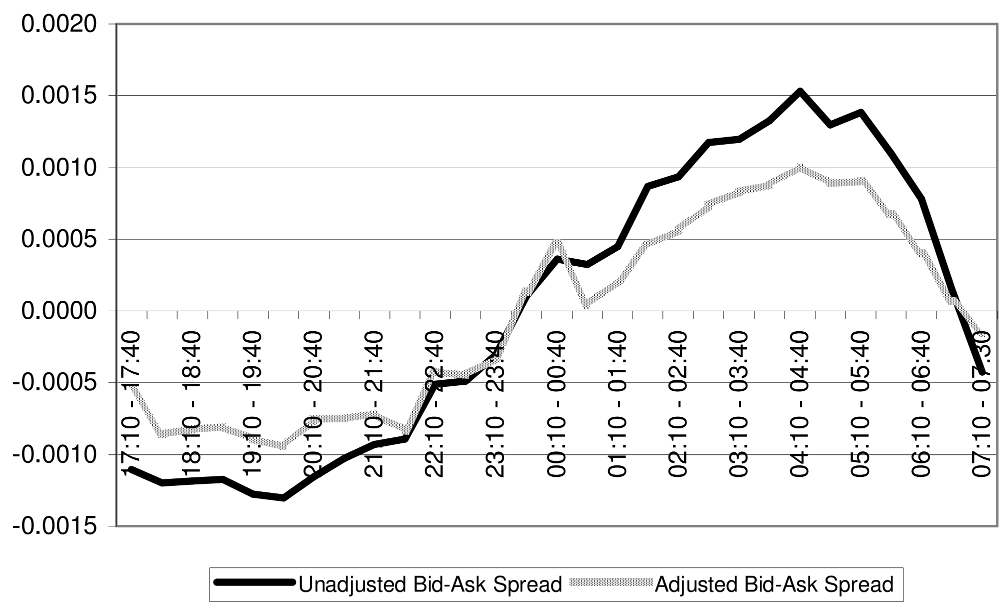
Our proxies for uncertainty with regard to the true price are positively related to the bid-ask spread and negatively to quoted depth. The absolute value of the percentage price change in the futures contract since the start of the night session is positive and significant. Time to maturity is positively related to the bid-ask spread and negatively related to quoted depth across all contracts. This is consistent with Frino and McKenzie (2002). The day of the week variables do not show a significant pattern, whereas US macroeconomic announcements have a significant positive impact on the bid ask spread in the 30 minute interval during which they take place (12.30pm AEST).

Figure 4. Adjusted and Unadjusted Intranight Pattern in the Bid-Ask Spread

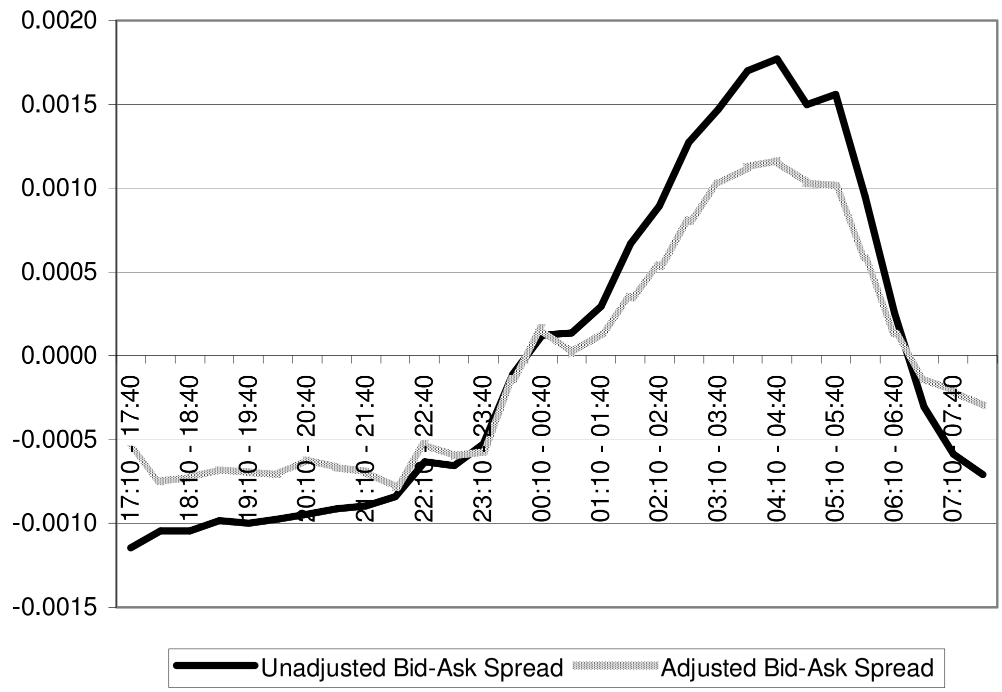
Panel A – SPI 200



Panel B – 90 Day BAB Futures



Panel C – 3 Year Bond Futures



Panel D – 10 Year Bond Futures

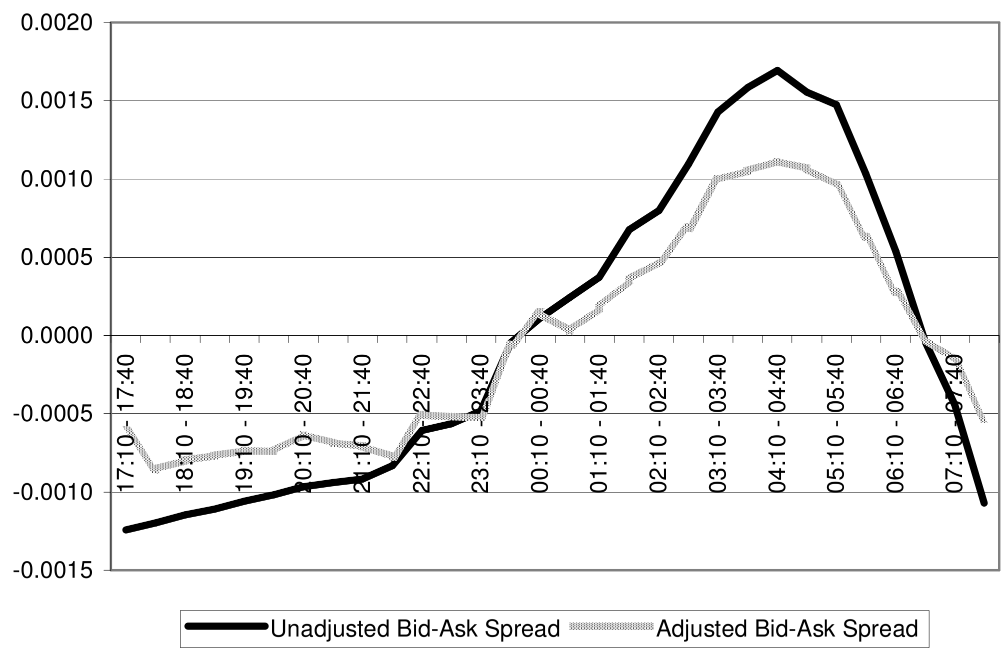


Table 3. Intranight Regression Results for the Multivariate Model of Liquidity[13]

Panel A – SPI200

	Coefficient	P-value		Estimate	P-value
Price	-0.0015**	0.0001	T2210	-0.0023**	0.0022
Volume	-0.0011**	0.0001	T2240	-0.0020**	0.0039
Volatility	0.4131**	0.0001	T2310	-0.0016**	0.0066
Local	-0.0024**	0.0001	T2340	-0.0014	0.4143
$(\text{Local})^2$	0.0013**	0.0001	T0010	0.0006	0.8745
Tuesday	0.0002	0.5442	T0040	0.0011	0.6739
Wednesday	0.0004	0.3200	T0110	0.0018	0.0329
Thursday	0.0004	0.2720	T0140	0.0020	0.1968
Friday	0.0006	0.1115	T0210	0.0031**	0.0003
TTM	0.0004**	0.0001	T0240	0.0035**	0.0001
$\left\lvert \frac{\overline{P}_t}{P_0} \right\rvert$	0.0499**	0.0001	T0310	0.0038**	0.0001
Bid-ask Spread - Bond	0.0416**	0.0001	T0340	0.0044**	0.0001
D_{US}	0.0024	0.0528	T0410	…	…
Intercept	0.0993**	0.0001	T0440	0.0039**	0.0001
T1740	-0.0016*	0.0333	…	…	…
T1810	-0.0035**	0.0001	T0710	0.0033**	0.0001
T1840	-0.0033**	0.0001	T0740	0.0028**	0.0008
…	…	…	T0800	0.0013**	0.0085

* Indicates significance at the 5% level.

**Indicates significance at the 1% level.

[13] This table reports the regression results of the equation:

$$BAS_t = a_0 + a_1 VOLATILITY_t + a_2 VOLUME_t + a_3 LOCAL + a_4 LOCAL^2 + a_5 \left\lvert \frac{\overline{P}_t}{P_0} \right\rvert + a_6 SPREADS\_BOND_t + a_7 P + a_8 TTM_t$$

$$+ a_{10} D_{US} + \sum_{i=1}^{4} \beta_i D_j + \sum_{ji=1}^{57} \gamma_j D_i + \varepsilon_t$$

on the SPI200, 90 Day BAB, 3 and 10 Year Bond futures contracts traded in the SFE over the night trading session during the period of 1 January 2002 to 31 December 2005. A 30-minute time period is used to segment the trading session into 29 intervals. Variables measured as per time interval include, in their order in the equation, volatility, trading volume, number of local traders, the square of number of local traders, the absolute value of the percentage price change, the bid ask spread of 10-year bond futures contract (dropped for interest rate regressions), the price level and the time to maturity. The last three dummy variables represent the US information announcement, the day of the week and the time intervals. Each dummy variable indicates the ending time of the 30-minute interval. For example, T2140 refers to the period from 21:10 to 21:40. The dummy variable representing the time period ending at 21:10 is excluded. The regression is estimated using Ordinary Least Square (OLS) with

Panel B – Interest Rate Futures

	90 Day BAB	3 Year Bond	10 Year Bond		90 Day BAB	3 Year Bond	10 Year Bond
Price	0.0001	0.0000	-0.0000	T2210	0.0013	0.0023	0.0023
Volume	-0.0024**	-0.0028**	-0.0015**	T2240	0.0204**	0.0120*	0.0099*
Volatility	0.5031**	0.4441**	0.3918**	T2310	0.0016	0.0021	0.0006
Local	-0.0016**	-0.0018*	-0.0011	T2340	0.0094*	0.0068*	0.0004*
$(\text{Local})^2$	0.0013*	0.0013*	0.0013	T0010	0.0001	0.0001	0.0001
Tuesday	0.0002	0.0003	0.0002	T0040	0.0016*	0.0009**	0.0011
Wednesday	0.0009	0.0005	0.0004	T0110	0.0018*	0.0013	0.0018
Thursday	0.0002	0.0002	0.0004	T0140	0.0017*	0.0008*	0.0012*
Friday	0.0006	0.0003	0.0011	T0210	0.0025*	0.0031*	0.0038*
TTM	0.0008**	0.0003*	0.0004**	T0240	0.0035*	0.0036	0.0040*
$\left\|\frac{\bar{P}_t}{P_0}\right\|$	0.0123**	0.0218**	0.0398**	T0310	0.0041*	0.0037*	0.0042*
D_{US}	0.0020**	0.0015**	0.0026**	T0340	0.0044*	0.0039*	0.0043*
Intercept	0.0939**	0.0801**	0.0456**	T0410	0.0051*	0.0040*	0.0045*
T1740	-0.0020*	-0.0011**	-0.0016*	T0440	0.0052**	0.0049*	0.0056**
T1810	-0.0015**	-0.0053**	0.0008	…	…	…	…
T1840	-0.0019*	-0.0028*	-0.0013*	T0710	0.0012	0.0028	0.0023
…	…			T0730	0.0016**	0.0011*	0.0013*

* Indicates significance at the 5% level.

**Indicates significance at the 1% level.

Of special interest is the pattern in the time dummy variables. Table 3 outlines the pattern in the intranight dummy variables for our model (1). We also present the time dummy variables for a model without the other explanatory variables in model (1). It can be seen from Figure 3 that inclusion of explanatory variables reduces the variation across intranight dummy variables. Nevertheless, there are still several distinctly different periods. First, in the first half hour after the opening of the

Newey and West adjustment method to correct for autocorrelation and Heteroskedasticity in error terms (Newey and West (1987)).

overnight session the spread decreases. After the first half hour the dummy variable estimates are approximately constant until midnight (AEST). After midnight, the spread increases sharply until 2am. It is in this period between midnight and 2:00am (AEST) that trading starts in US interest rate futures (22:20 AEST) and US stocks and stock index futures (01:30). Furthermore, the most important macro-economic announcements in the US are typically made at 8:30am NY time, which is 23:30 AEST. In the period between 2:00am (AEST) and 6:00am (AEST) the interval dummies flatten out until dropping sharply in the final half hour of the overnight session. In a more formal test we can not reject the hypothesis that the interval dummies are equal between 17:10 and midnight (p-value is 0.08), and that the time interval dummies are the same for the period from 02:00 through to 06:30 (p-value is 0.12).

In summary, much of the pattern in the intranight bid-ask spread can be explained by variables typically used in cross-sectional models of the bid ask spread, changes in the trading population during the night, variables that proxy for the evolution of pricing risk throughout the night, the opening of the US equity and futures markets and US macro-economic announcements. After controlling for these influences, the pattern in interval dummies provides support for the revelation of information in the first half hour of trading (Madhavan, 1992). The evidence also indicates that information asymmetry increases from the half hour before the opening of the US interest rate futures markets until a half hour after the opening of the US stock markets, and stays at a higher level during the rest of the trading night. This result supports the contagion model in King and Whadhani (1990). The sharp drop in the dummy variables in the last half hour is in line with other research of competitive dealer markets that liquidity increases towards the close of trading. Our results that the increase in liquidity towards the close takes the form of narrowing bid-ask spreads and higher quoted depth. Note that in contrast to earlier research, our finding is obtained after accounting for changes in trading volume, volatility and other explanatory variables.

5. Conclusion

This paper examines "intranight" patterns in quoted bid-ask spreads and depth, price volatility and trading volume in the SPI200, 90 Day BAB, 3 Year Bond and 10 Year Bond futures contracts. We attribute the documented overnight pattern in liquidity to three factors: (1) The elevation in both price volatility and trading volume at the open and close of overnight trading sessions is consistent with strategic trading models proven in earlier work of daytime markets; (2) US macroeconomic information and (3) contagion effects from price behaviour in overseas markets. Elevation in volume, volatility and bid-ask spreads combined with depressed levels of quoted depth around the opening of US futures and equity markets is consistent with prior literature examining contagion effects. In contrast to prior research, we document an upside down U-shaped pattern in quoted bid-ask spreads, with spreads narrowest at the open and close of the intranight session. Quoted depth follows a U- shaped pattern, where depth is deepest at the open and close of the intranight session. Further tests indicate that the intranight pattern in the bid ask spread and quoted depth can be largely explained by variables typically used in cross-sectional models of the bid ask spread, changes in the trading population, the opening of the US markets and US announcements and variables that proxy for the evolution of pricing risk throughout the night.

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