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BID-ASK SPREADS, TRADING VOLUME AND VOLATILITY: INTRA-DAY EVIDENCE FROM THE LONDON STOCK EXCHANGE

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INTRODUCTION

Recent empirical research on equity markets, using quote and transactions data, has revealed intra-day regularities in bid-ask spreads, volatility and measures of trading activity in a variety of institutional settings. For example, it was first documented that there is a U-shaped pattern in spreads and volume, for stocks on the New York Stock Exchange, during trading hours. The recent availability of intra-day data from non-US equity markets has also spurred investigations of intra-day regularities in diverse institutional settings.

Research in this area is important for three reasons. First, existing literature on intra-day seasonalities is largely concentrated on the NYSE with its trading system centred around the specialist. It would be of great interest to extend existing empirical work to a dealership market such as the London Stock Exchange,[1] the third largest stock exchange in the world by turnover and market value.[2] Secondly, it would be useful to examine whether the intra-day variation of spreads, volume and volatility are consistent with the predictions of theoretical models such as those of Admati and Pfleiderer (1988) or Brock and Kleidon (1992). Finally, research relating to the systematic behaviour of these variables should be of relevance to market participants as well as regulators and policy makers involved in the design of efficient trading systems.

This paper contributes to the literature in the following ways. First, it documents intraday variations in the bid-ask spread, trading volume and volatility of returns, based on a large sample of 835 stocks, traded during the first quarter of 1991. Second, it tests the predictions of two major theoretical models of intraday behaviour in the context of observed regularities on the London Stock Exchange. Third, the paper also presents qualitative evidence on the intraday behaviour of a number of interesting variables; trading volume

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per transaction, the number of transactions during each fifteen minute interval and spreads/volume across stock portfolios of varying liquidity. Finally, the intra-day period studied also focuses on a specific feature of the London Stock Exchange; the two periods in the market prior to and after the main trading period during which market-makers are not obliged to trade or post quotes.

The results can be summarized as follows. First, the average bid-ask spread shows a U-shaped pattern during trading hours, similar to that seen in many other markets. The spread is highest at the open, falling rapidly to a constant level and widening again slightly at the close. Similar patterns are seen for portfolios of the sample stocks partitioned into deciles on the basis of trading volume. Second, trading volume, in contrast to the spread, is not U-shaped. It shows a double-humped pattern with highs at 9.30 a.m. and then at 4.00 p.m. prior to the close. The trading patterns for the highest and the lowest traded stocks, however show a different pattern from that for the entire sample. Thirdly, return volatility, shows a U-shaped pattern. Finally, the results of the statistical tests provide mixed support for the models of Admati and Pfleiderer (1988) and Brock and Kleidon (1992).

The outline of the paper is as follows. In the next section, the previous empirical work and the relevant theoretical models are briefly reviewed. The third section describes some features of trading on the London Stock Exchange, the data set and the statistical methodology used. The results of the empirical analysis follow in the fourth section and the final section contains a summary and conclusions.

REVIEW OF PREVIOUS EMPIRICAL WORK

Early empirical research on intra-day patterns in spreads and trading activity is based on data from the NYSE, a specialist market, and reflects its particular institutional features. McInish and Wood (1990a) and Wood, McInish and Ord (1985) find a high variance of returns at the beginning and at the end of the trading day. Foster and Viswanathan (1990) also observe a U-shaped pattern in the variance of price changes of NYSE stocks by hour of the day. Evidence of a U-shaped pattern in the intra-day volume is reported by Jain and Joh (1988), Foster and Viswanathan (1990) and Gerety and Mulherin (1992).

Relatively less attention has been directed at the NASDAQ which is a dealership market similar in some ways to the London Stock Exchange. Chan et al. (1993) find that the inside spread, for NASDAQ stocks, attains its highest level immediately following the opening of the market, declining steadily thereafter and then narrows abruptly during the last hour of trading. They also observe that intraday variations in volume shows strong evidence of a U-shape. Finally, they report that volatility is high at the open, declining thereafter with a slight rise at the close.

The availability of quote and transactions data has led to the extensions of work on intra-daily seasonalities in other national stock exchanges. McInish and Wood (1990b) report that for stocks traded on the Toronto Stock Exchange, both returns and volume show a U-shaped pattern. Hamao and Hasbrouck (1993) find, for stocks traded on the Tokyo Stock Exchange, that the mean-squared return and the bid-ask spread tend to be higher at the beginning and the end of the trading day. They also observe that intra-day trading volume is higher at the beginning and the end of each of the two trading sessions during the day. Niemayer and Sandas (1993) and Aitken, Brown and Walter (1993) provide similar evidence of intra-day regularities on the Stockholm and the Australian SEATS trading system. Kleidon and Werner (1993), is the only other study we are aware of, which investigates intraday regularities for stocks traded in the London Stock Exchange. Their study, however, differs from the present in two important respects. First, their focus was to examine the intra-day behaviour of stocks which were traded dually on the London and US exchanges. Secondly, they use data on 79 FTSE-100 stocks for about five months. Our reported results are based on data for the first quarter of 1991 containing 835 stocks. In addition, a similar analysis was carried out on data from the first quarter of 1990 for 147 stocks, where the results (not presented here to conserve space) were qualitatively similar to those reported here.

There are currently two major models of concentrated trading in financial asset markets. The Admati and Pfleiderer (1988) model relies on the behaviour of some uninformed (liquidity) traders who strategically execute their trades in order to minimize their trading costs. The market closure model of Brock and Kleidon (1992), on the other hand, relies on portfolio re-balancing at trading halts based on the idea that the optimal portfolio is a function of the ability to trade. These alternate models of concentrated trading predict different patterns in spreads, volume and volatility. The main testable predictions of the two models of intraday behaviour are summarized below. The first, is the Admati and Pfleiderer (1988) model which suggests that:

(a) Volume will be concentrated during the day.
(b) Depth and volume are negatively correlated due to the competition among the informed traders and the market depth provided by the uninformed traders.
(c) Volume and volatility are positively correlated due to the presence of informed traders.

The second model, is that of Brock and Kleidon (1988) which has the following testable implications:

(a) Volume will be U-shaped during the day.
(b) Volume and spreads are positively correlated due to the increased

liquidity demand at the open and close. Therefore, spreads are U-shaped during the day.

(c) Volatility is independent of volume and spreads because information arrival is constant and thus follows no intraday pattern.

The availability of intraday data on spreads, volume and return volatility should make it feasible to test some of these propositions.

INSTITUTIONAL BACKGROUND, THE DATA SET AND TEST METHODOLOGY

Institutional Background

In October 1986, a series of reforms were introduced on the London Stock Exchange termed as 'Big Bang. These included the introduction of an electronic screen-based trading system called the Stock Exchange Automated Quotation System or the SEAQ. Though the SEAQ trading system is similar to that of the NASDAQ, the former has several unique features. Market makers on the SEAQ are obliged to quote two-way prices, during the Mandatory Quote Period (thereafter MQP), for the stocks in which they are registered to deal. These quotes are valid for a specific quantity called the Nominal Market Size (NMS). This NMS, which is determined by the Exchange, is based on customer turnover in each stock over the previous twelve months expressed in a number of shares (ranges currently from 500 to 200,000 shares). During the first quarter of 1991 there were on average ten to twelve market makers per active stock on the SEAQ. Market makers are eligible for relief from stamp duty, stock borrowing for short sales and access to the Inter-Dealer Brokers' system (IDB). Another feature of trading on the London Exchange is that about sixty per cent of trading is by institutional investors as compared to a more retail-oriented market like the NASDAQ. As a result, order flow on the London Exchange is characterized by large, infrequent trades on one side of the market.

There are some institutional features[4] of the London Stock Exchange that are relevant to the intra-day behaviour of spreads, volume and volatility and contrast with those of both the NASDAQ and the NSE. The trading day on the London Stock Exchange (details are shown in Table 1) consists of the pre-market period during which users log on to the electronic system and receive/down-load trade reports. From the time the SEAQ opens till the start of the Mandatory Quote Period (from 7.15 am to 8 am), market makers are not obliged to, but may post quotes. Quotes if posted, are however firm for the quantities indicated. During this Mandatory Quote Period, all market makers are obliged to post firm quotes for all their stocks. Further, market makers are not obliged to post quotes in the time interval from the end of the MQP to the close of the SEAQ (from 4.30 pm to 4.45 pm). During this period market makers gradually exit the system. The Australian SEATS system, as described in Aitken, Brown and Walter (1993), also provides for a similar regime. The NASDAQ market system does not, however, have similar pre- and post-Mandatory Quote Period sessions.

In contrast to the NYSE, where the specialist can observe the entire order flow in determining opening prices, market makers in quote-driven systems like the London Exchange or the NASDAQ face a more fragmented order flow. NASDAQ dealers, for example, are required to search for equilibrium prices by observing trade induced by market quotes after trading commences. The widening of the spread at the close for stocks on the NYSE has been attributed to the privileged knowledge, which the specialist has of market-on-close orders. The NASDAQ system does not have this feature and Chan et al. (1993) suggest that this allows dealers to post quotes which narrow the inside spread.

The Data Set

The data used for the current study was obtained from the London Stock Exchange. It consists of time-stamped (to the nearest second) and date-stamped intra-day bid-ask quotes and matched transactions prices and volumes covering the period 1 January, 1991 to 31 March, 1991 i.e. for the first quarter of 1991. The data is in two separate quote and transaction files. The quote file consists of bid-ask quotes posted by market makers from the SEAQ open to its close for all the securities included in that quarter. The data includes the security code, the ask price and the bid price as well as the start and end time (to the nearest second) during which the quote was valid. In addition, both bid and ask volume are available. The transactions file consists of reports from both buyer and seller matched by the Stock Exchange. The tapes represent an audit trail and records are matched to within 'jobber's tolerance' on a number of fields such as quantity, price, currency code etc. Each record consists of a security code, the date on which the trade took place, the trade price, a currency indicator and the quantity bought and sold.

We report detailed results only for the first quarter of 1991 for a sample of 835 stocks. Summary details for this data are reported in Table 2. As indicated there, the sample is diverse and contains both highly liquid as well as infrequently traded stocks.

The Methodology

Details of the choice of intra-day time interval used, the measures used for obtaining the intra-day variables and the statistical tests procedure used for the intra-day seasonalities are now provided.

First, the trading day was divided into 44 separate fifteen minute intervals from 07:00 hours to 18:00 hours i.e. before the SEAQ Pre-market open to the SEAQ close. This time interval was chosen for the analysis for two reasons.

Table 1

Summary Information on the Trading Day

	Post 26 March, 1990
SEAQ Pre-Market (Users may log on, receive down-load trade reports)	0715
SEAQ Open (Users may do all above plus enter quotes)	0800
Mandatory Quote Period (MQP)	
Start	0830
MQP End	1630
SEAQ Close	1645
Actual or SEAQ System Close	1715

Table 2

Summary Information on the Data Set

Variable	*1991 Quarter 1*
Number of stocks	835
Calendar Days in Sample	55
Maximum Total Volume Traded in a Stock	57 million
Minimum Total Volume Traded in a Stock	151
Maximum Total Transactions in a Stock	53,393
Minimum Total Transactions in a Stock	1
Number of records in Quotes File	1,262,456
Number of Records in Transactions File	1,628,682

First, the changes in the timing of the MQP occurred at half-hour intervals and a 15-minute interval would better indicate the variations within the pre- and post-MQP periods. Second, the size of each time interval allows a meaningful interpretation of the intraday dummy variables used as well as smoothing the graph of the series used.[5]

This study focuses on the following intra-day variables: the bid-ask spread, the trading volume, number of transactions and the volatility of mid-quote returns. First, for each stock *(i)*, for each trading day *(j)* in the sample, we obtain the best 'inside' quote i.e. the lowest ask and highest bid straddling the end of each interval *(t)* i.e. at 07:15, 07:30, ..., up till 18:00 hours. The proportional bid-ask spread, is then calculated as:

$$\text{BAS}_{i,j,t} = \frac{\text{ASK}_{i,j,t} - \text{BID}_{i,j,t}}{[\text{ASK}_{i,j,t} + \text{BID}_{i,j,t}]/2}. \quad (1)$$

These 15-minute proportional spreads are then averaged for all trading days for a stock and then across all the stocks in the sample. In addition a series of proportional bid-ask spreads for each stock for each trading day divided by the mean of the series for that day is also obtained i.e. where the intraday spread is expressed as:

$$\mathrm{SBAS}_{i,j,t} = \frac{\mathrm{BAS}_{i,j,t}}{\text{Avg. BAS across } N \text{ intra-day intervals}} \qquad (2)$$

where i = stock, j = trading day and N = total number (44) of 15-minute intervals during the day. This standardized measure[6] is used in regression-based statistical tests.

Next, the transactions data is used to obtain the trading volume (i.e. the total number of stocks bought or sold) and number of transactions (the number of individual transactions for a specific quantity of shares) in each fifteen-minute interval from 07:00 to 18:00 hours every day. The trading volume and number of transactions in each interval are then cumulated across days for each stock and then over all stocks to obtain the total trading volume and number of transactions in each fifteen-minute interval. The volume variable is denoted by $\mathrm{Vol}_{i,j,t}$.

Finally, to obtain an estimate of intra-day return volatility, we utilize the inside quotes obtained earlier to get a mid-quote price for each security i and trading day j. These prices are then used to obtain returns over every fifteen minute interval during the day, as follows:

$$R_{i,j,t} = \log_e \frac{M_{i,j,t}}{M_{i,j,t-1}} \qquad (3)$$

where $M_{i,j,t}$ = the mid-point of the bid ask spread in minute t and, $M_{i,j,t-1}$ = the mid-point of the bid-ask spread at minute $t-1$. Returns are then averaged across trading days and stocks. We use the absolute value of the returns as a measure of the volatility during that period. The use of mid-quote prices rather than transactions prices should reduce spurious volatility due to bid-ask bounce.

The quote and the transactions data files contain 'raw' unfiltered data. A variety of filters were therefore used to screen the data. These included percentage filters for the quote data and adherence to relationships such as ask price being greater than the bid price etc. For the transactions data, filters for currency codes, split trades etc. were also included so as to ensure the accuracy of the calculated variables. The graphical results are reported using the bid-ask spread, volume and absolute volume of the return series obtained as indicated above. For the statistical tests we standardized the variables used by dividing each observation by its time series mean for each day.

The statistical significance of each variable of interest, the bid-ask spread, trading volume and volatility during the intra-day period, was tested by running three separate regressions of the form:

$$W = c_0 + \sum_{i=1}^{n} c_i D_i + \sum_{k=\mathcal{N}-n}^{\mathcal{N}} c_k D_k + e_{i,t} \tag{4}$$

where W represents the variables, $\mathrm{SBAS}_{i,j,v}$, $\mathrm{Vol}_{i,j,t}$ and $\mathrm{R}_{i,j,t}$, respectively, obtained as described above in equations (1), (2) and (3). In the regression c_0 is a constant, c_i's are the coefficients and D is the indicator variable taking the values $\{0,1\}$ and e is the error term. The focus of each regression is to study changes in the dependent variable at the beginning and at the close of the market,[7] relative to activity during the middle of the day since the theoretical models make specific predictions about these periods. The choice of the actual number of intervals to be included at the beginning and end of the day (i.e. the choice of n) was based on the prior graphical analysis. To estimate the regressions, we use Hansen's (1982) Generalized Method of Moments (GMM) technique using the Newey and West (1987) correction for serial correlation, as in Foster and Viswanathan (1993). GMM estimates are robust to the presence of autocorrelation and heteroscedasticity, both of which we would expect to find in this type of data. In our case, since the system is just identified, the GMM estimates are identical to those from OLS although their standard errors are different. We test the null hypothesis that all the interval dummies included in the regression are equal to zero using a χ^2 test. A large χ^2 statistic means that at least one of the fifteen-minute interval dummy variables has a coefficient that is significantly different from zero. The size of the coefficient also indicates the relative importance of that time-interval with reference to average over the intervals used in the estimation.

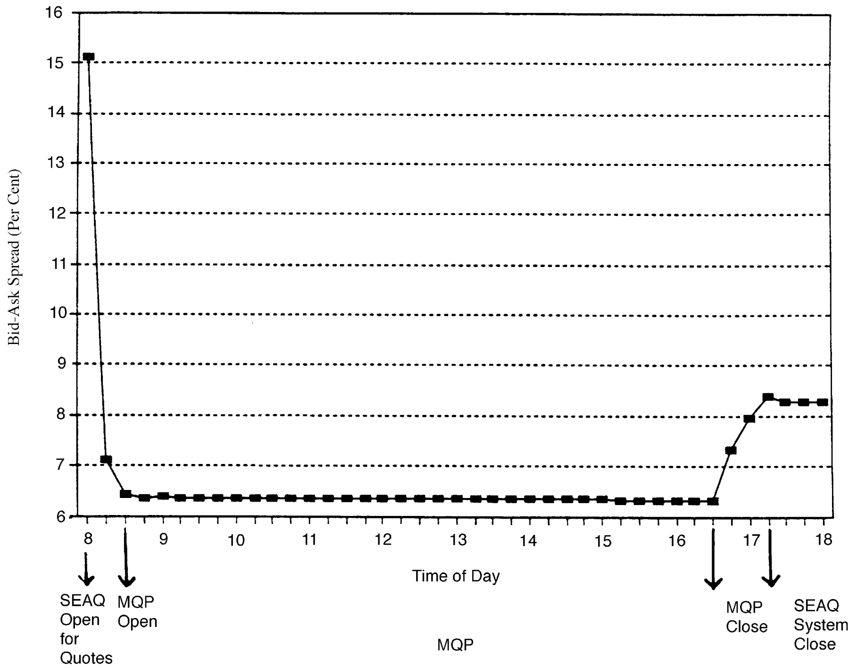
EMPIRICAL RESULTS

The empirical results on the intra-day changes in the bid-ask spread are presented graphically in Figure 1. They suggest that the proportional bid-ask spread (BAS) is at its widest from the SEAQ open (at 08:00 hours) to 08:30 hours when the Mandatory Quote Period starts. Thereafter, the spread falls rapidly and is almost constant through the day. It then again widens slightly after the end of the MQP, at 16:30 hours, till the SEAQ close. Kleidon and Werner (1993) however, find for their sample, that the inside spread declines over the MQP period.

The formal tests of the intraday variation in the inside spread are reported in Table 3. The coefficients are interpreted as follows. The value 0.0877 during the first interval of the trading day, indicates that the percentage inside spread during that period was larger than the average during the 12 intervals used in the estimation. During the MQP, the size of the coefficients are almost the same indicating little change in the inside spread. The restriction that the dummies for each of the 12 intervals are zero is also formally tested. This is a direct test of whether there are any intra-day variations in the inside spread.

Figure 1

Intra-Day Bid-Ask Spreads
1991 Q1: 0800 – 1800



In this case, the test statistic is χ^2 distributed with 12 degrees of freedom. The null hypothesis that the inside spread is constant across the beginning and the end of the day can clearly be rejected at conventional levels of significance. The results of the tests support the prediction of the Brock and Kleidon (1992) model which predicts wider bid-ask spreads at the market open and the close.

Brock and Kleidon (1992) attribute this widening of the spread at the open and the close to the actions of the specialists who can price discriminate at the open and the close of the market when investors have less elastic demand function. In the institutional framework of the NASDAQ, Chan et al. (1993), suggest that the inside spread of NASDAQ dealers should narrow at the close due to inventory control. Individual dealers who have accumulated too much or too little inventory may post bid or ask quotes that better the previous inside spread to attract orders. In contrast to the finding of Chan et al. (1993) we find, for the SEAQ data, that there is a widening of the spread at market open and close. We conjecture that on the London SEAQ, the pre-MQP period probably provides market makers on the London Stock Exchange with an opportunity to search for equilibrium prices by observing

Table 3

Results of the GMM Estimation of Intra-Day Variation in the Inside Bid-Ask Spread (SBAS)

$$W = c_0 + \sum_{i=1}^{i=n} c_i D_i + \sum_{k=N-n}^{N} c_k D_k + e_{i,t}$$

Variable	*1991 Quarter 1*
constant	0.0646 (0.0005)
c_1	0.0877 (0.0003)
c_2	0.0079 (0.0013)
c_3	0.0007 (0.0009)
c_4	0.0002 (0.0009)
c_5	0.0003 (0.0009)
c_6	0.0003 (0.0009)
c_{36}	−0.0004 (0.0009)
c_{37}	−0.0003 (0.0009)
c_{38}	0.0062 (0.0033)
c_{39}	0.0321 (0.0104)
c_{40}	0.0339 (0.0085)
c_{41}	0.0359 (0.0087)
$\chi^2(12)$ (p-value)	109281 (0.0000)

Notes:
Values in parenthesis are standard errors adjusted for autocorrelation and heteroscedasticity using Hansens' (1982) correlation. $\chi^2(12)$ is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

the sequence of market makers' quotes posted from the SEAQ open until the start of the MQP. This search process is associated with price uncertainty leading to wider spreads at the open. Further, the end of the MQP also sees a widening of the spread coinciding again with the period of greater price uncertainty as market makers gradually leave the system till close down.

Next, it is interesting to see qualitatively the evolution of activity in the

Table 4

Results of the GMM Estimation of Intra-Day Variation in Trading Volume (Vol)

$$W = c_0 + \sum_{i=1}^{i=n} c_i D_i + \sum_{k=N-n}^{N} c_k D_k + e_{i,t}$$

Variable	*1991 Quarter 1*
constant	0.0285
	(0.0007)
c_1	−0.0228
	(0.0010)
c_2	−0.0158
	(0.0012)
c_3	0.0034
	(0.0026)
c_4	0.0068
	(0.0032)
c_5	0.0102
	(0.0037)
c_6	0.0062
	(0.0016)
c_{36}	−0.0111
	(0.0021)
c_{37}	−0.0091
	(0.0152)
c_{38}	−0.0260
	(0.0013)
c_{39}	0.0274
	(0.0011)
c_{40}	−0.0279
	(0.0007)
c_{41}	−0.0276
	(0.0008)
$\chi^2(12)$	2346.04
(p-value)	(0.0000)

Notes:
Values in parenthesis are standard errors adjusted for autocorrelation and heteroscedasticity using Hansens' (1982) correlation. $\chi^2(12)$ is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

posting of quotes prior to and after the MQP and the contemporaneous variation in the inside spread. This is depicted in Figure 2. These graphs suggest that, prior to the start of the MQP, the number of quotes posted rises rapidly till the start of the MQP after which they reach a plateau. After the end of the MQP, the number of quotes posted drops rapidly till the 'close' of the SEAQ system. Clearly, prior to the MQP, market makers enter the system

Figure 2

Bid-Ask Spreads & No. Quotes
1991 Q1: 0800 – 1800

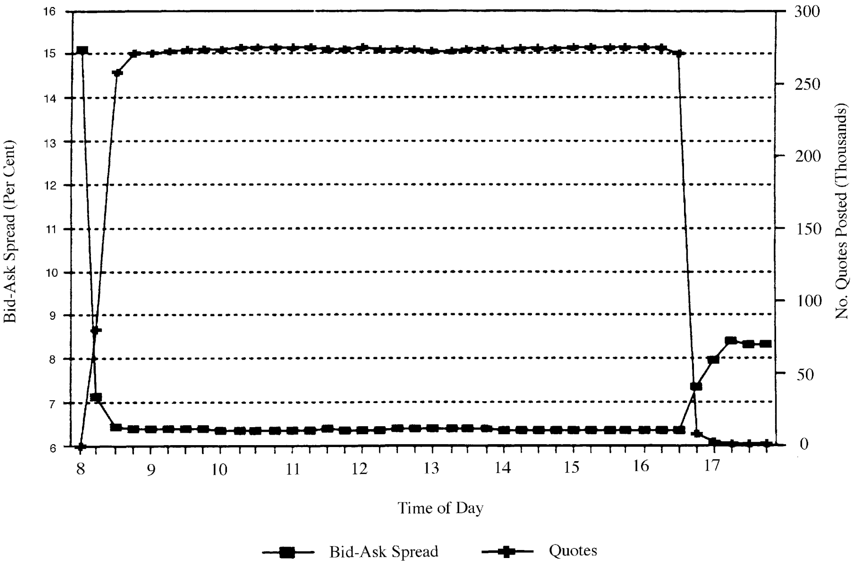


Figure 3

Bid-Ask Spreads & Volume
1991 Q1: 0800 – 1745

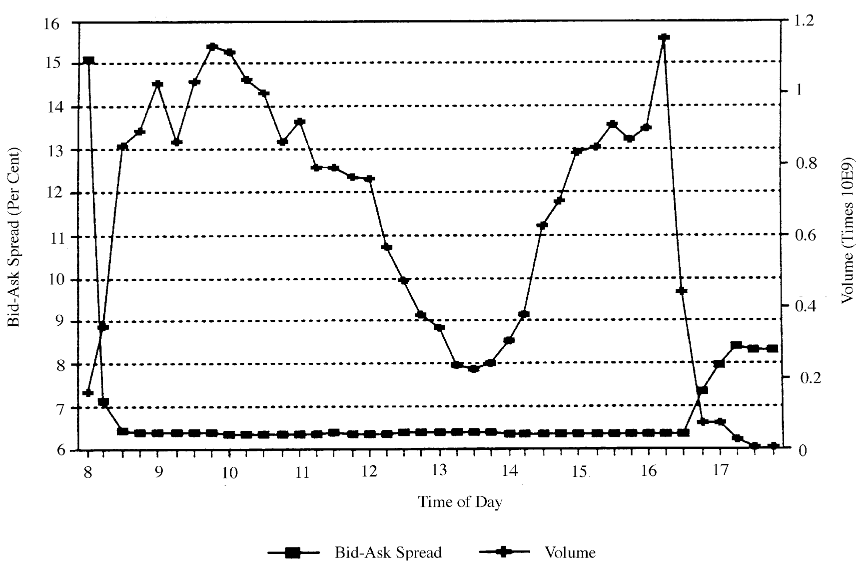
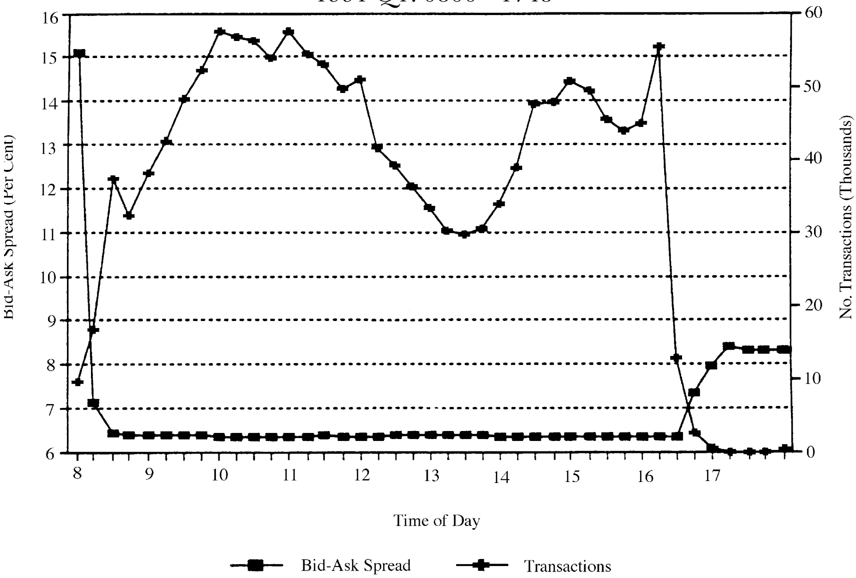


Figure 4

Bid-Ask Spreads & Transactions
1991 Q1: 0800 – 1745



at various stages. Similarly, at the end of the MQP, they exit the SEAQ system in a similar fashion. According to SEAQ practice, quotes posted outside the MQP are not firm. However we can see from Figures 3 and 4 that during these two 'windows' there is a steady rise in the volume of stocks traded as well as the number of transactions made.

Figures 6 and 7 depict the intra-day variation in the bid-ask spread in both samples partitioned on the basis of trading volume and number of transactions. The large and diverse sample used shows a wider dispersion of bid-ask spreads across trading deciles. An inverse relationship between the bid-ask spread and the trading frequency can be clearly seen.

The intraday variation in volume, shown in Figure 3 alongside the spread, suggests a two-humped pattern over the MQP. In order to investigate this further, fifteen-minute trading volume for stocks in the highest and the lowest decile by trading volume were obtained. The results, in Figure 8, show that low liquidity stocks have a low trading volume at the start with a steady rise till mid-day and falling to their lowest level at 'lunch time'. Volume then rises sharply reaching a maximum before the end of the MQP. For stocks in the highest traded decile, however, a more definite U-shaped pattern is visible. It is possible that the differential trading patterns among stocks of different liquidities produces the two-humped structure in the aggregate sample similar to that observed by Kleidon and Werner (1993). Handa (1993) also observes a

Figure 5

Volume Per Transaction
1991 Q1: 0800 – 1745

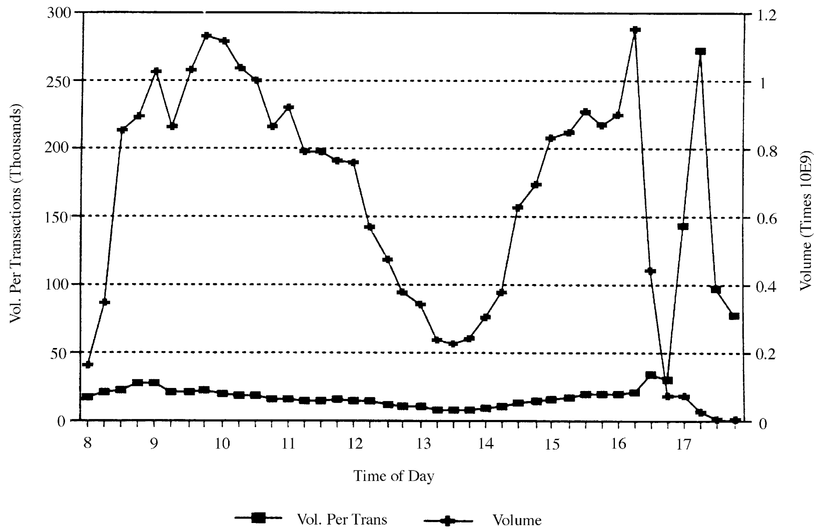


Figure 6

Spread by Time by Volume
1991 Q1: 0800 – 1745

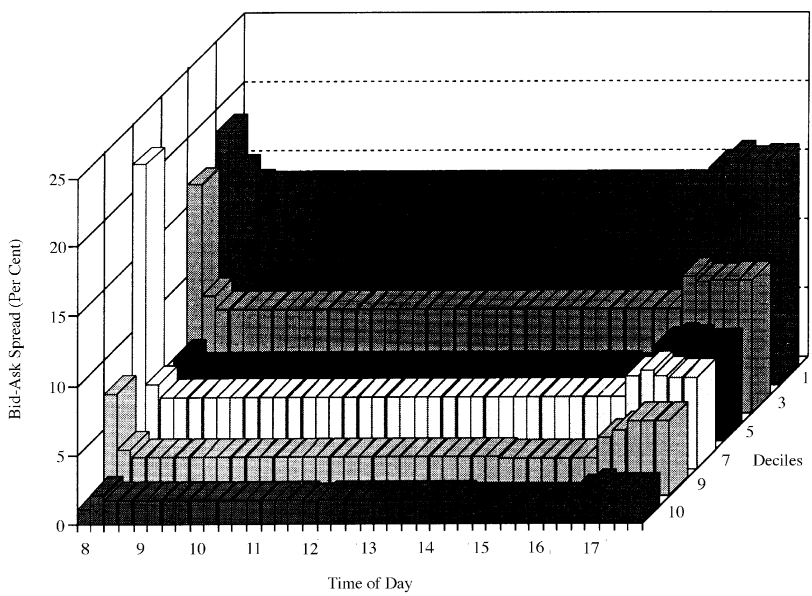


Figure 7

Spread by Time by Trading Frequency
1991 Q1: 0800 – 1745

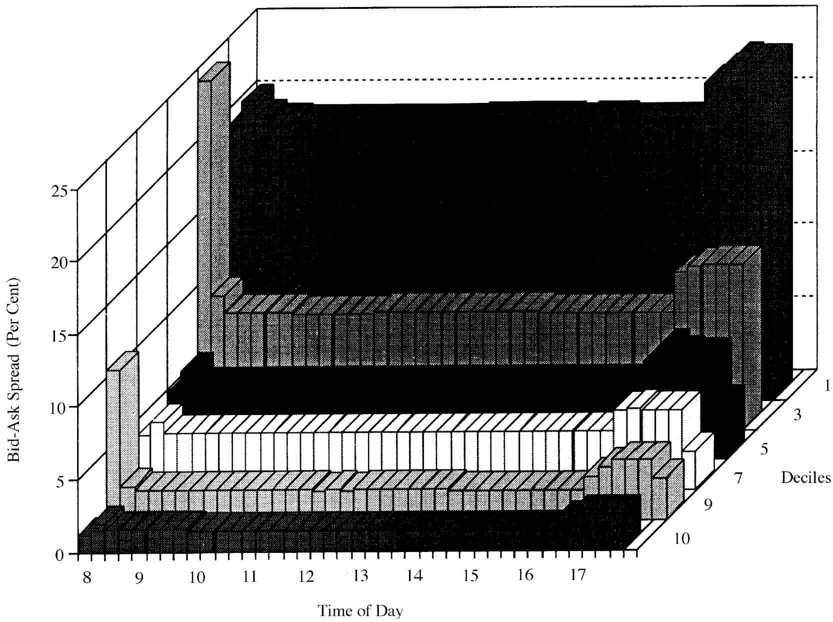


Figure 8

Intra Day Trading 1991Q1
Thin and Heavy Traded Stocks

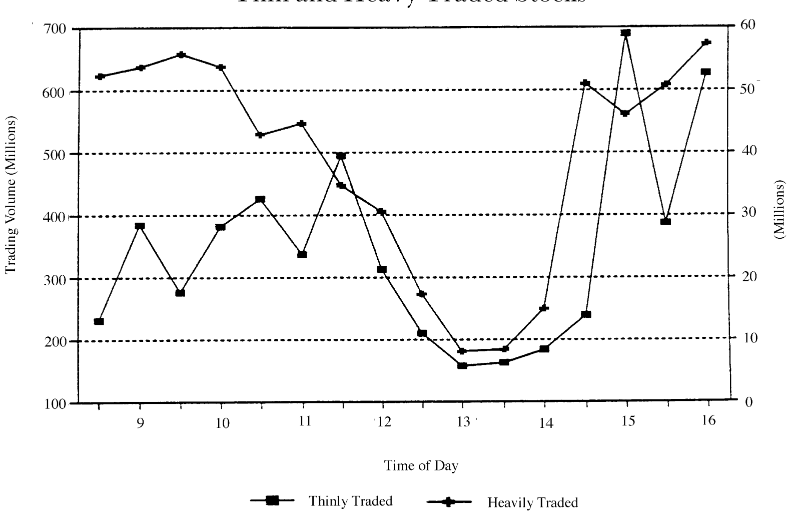


Table 5

Results of the GMM Estimation of Intra-Day Variation in Mid-Quote Return Volatility (R)

$$W = c_0 + \sum_{i=1}^{i=n} c_i D_i + \sum_{k=N-n}^{N} c_k D_k + e_{i,t}$$

Variable	*1991 Quarter 1*
constant	0.0001
	(0.0001)
c_1	0.0026
	(0.0013)
c_2	0.0037
	(0.0015)
c_3	0.0011
	(0.0014)
c_4	0.0012
	(0.0015)
c_5	0.0003
	(0.0008)
c_6	−0.0007
	(0.0008)
c_{36}	−0.0016
	(0.0013)
c_{37}	−0.0035
	(0.0013)
c_{38}	0.0033
	(0.0012)
c_{39}	0.0008
	(0.0010)
c_{40}	−0.0083
	(0.0074)
c_{41}	−0.0001
	(0.0001)
$\chi^2(12)$	34.44
(p-value)	(0.0000)

Notes:
Values in parenthesis are standard errors adjusted for autocorrelation and heteroscedasticity using Hansens' (1982) correlation. $\chi^2(12)$ is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

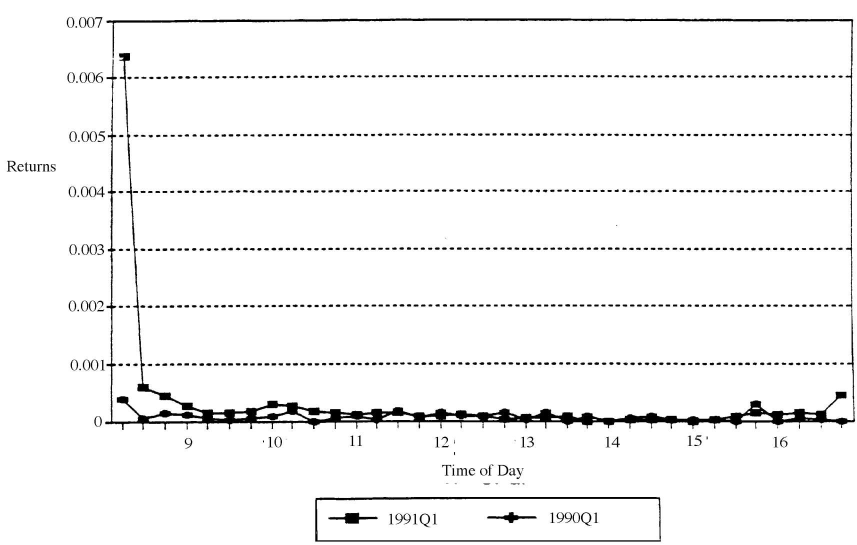
difference in the intra-day trading volume patterns for NYSE stocks on the basis of market capitalization deciles. Interestingly, the average volume of stocks traded per transactions, Figure 5, is fairly constant through the day, with some rise at the start and before the end of the MQP.

Formal statistical tests on the basis of the GMM estimations, for intraday volume variations, are reported in Table 4 and confirm the pattern in volume seen, in the graph in Figure 3 during the MQP. As in the test for the variation in the inside spread, we can reject the null hypothesis that the trading volume is constant across all the fifteen-minute intervals at the beginning and at the end of the trading period. The size of the coefficients also support the results presented in Figure 3. The Brock and Kleidon (1992) model predicts that trading volume is highest at the open and at the close as are spreads. However, in the case of the London Stock Exchange, volume is not highest at the open and the close. In fact, average volume peaks occur, over the entire sample, at about 09:30 and 16:15 hours. It is also interesting to note that, the average volume per transaction, is fairly constant through the day as seen in Figure 5. The variation in volume supports the idea in Admati and Pfleiderer (1988) who suggest that periods of concentrated trading may occur at some points in the day not necessarily at market open or close.

Finally, evidence is presented in Figure 9, on the intra-day variation in return volatility based on the absolute value of the mid-point of the bid-ask spread. This measure of return volatility to avoid the spurious volatility associated with bid-ask bounce based on transactions returns. The graph shows that the volatility is high during both the pre- and the post-Mandatory Quote Periods (MQP) periods. During the MQP, volatility is slightly higher at the open and the close than that at the middle of the MQP. The increased volatility outside the pre-MQP period is similar to that reported for studies of

Figure 9

Midquote Absolute Returns
1990Q1 & 1991Q1



the both specialist and NASDAQ markets. Table 5 presents the results of our tests on variations in intra-day volatility. As in the other two cases we reject the null hypothesis that volatilities are constant across the time intervals chosen at the beginning and at the end of the day. The results of the regressions and the size of the coefficients provide confirmation for the increased volatility seen outside of the MQP in both the samples. The results suggest that volatility is high at the open and close similar to the bid-ask spread but not similar to the observed pattern in the volume of trade. This empirical observation is not supported by the predictions of either the Admati and Pfleiderer or the Brock and Kleidon models.

SUMMARY AND CONCLUSIONS

This paper examines the intra-day variation in the inside bid-ask spread, trading volume and volatility for a sample of 8,235 stocks traded on the London Stock Exchange during the first quarter of 1991. The results can be summarized as follows. First, intraday spreads are highest at the market open, relatively constant through the day and widen again slightly at the close. The pattern of spreads is similar across deciles of stocks partitioned on the basis of liquidity. Trading volume, on the other hand peaks at about 09:30 hours and falls thereafter to a low at about 13:30 hours. It then rises again prior to the close of the MQP peaking again at 16:00 hours. Interestingly, the average volume traded per transaction is relatively flat during the day with slight rises at about 09:30 hours and 16:00 hours. Further, the pattern of trading volume per fifteen-minute interval is different for liquid and illiquid stocks. Finally the return volatility is highest at the open but relatively flat during the day, rising only slightly at the close of the market. The evidence in support of the two main theories of intraday behaviour is very mixed. The conjecture of Admati and Pfleiderer that volume will be concentrated at some time during the day finds support. However volume and volatility do not appear to be correlated. The prediction of the Brock and Kleidon model that spreads will be U-shaped finds support. However, little evidence is found for their proposition that volatility does not follow any intra-day pattern.

Clearly, the evidence from the London Stock Exchange, in favour of the two major models of Admati and Pfleiderer and Brock and Kleidon is mixed. It is important that the predictions of theoretical models are tested in a variety of institutional settings so as to examine their robustness. It is important that the predictions of theoretical models are tested in a variety of institutional settings so as to examine their robustness. It is felt that there is room for a model of intraday behaviour that can encompass the empirical findings in dealership markets such as SEAQ and the NASDAQ. Further, it would also be interesting to analyze the differential behaviour of liquid and illiquid stocks further. Finally, the results suggest that the bid-ask spread is higher during the two 'windows' when the market is open but market makers are not obliged to post quotes i.e. outside the Mandatory Quote Period. It would be of interest to focus on the order flow and spreads in these two periods specifically.

We conclude that the interpretation of intra-day seasonal effects is closely related to the unique institutional features of the market being studied. The behaviour of market variables especially at the close and the open appears to be closely linked to the process of price discovery which in turn is sensitive to mechanism by which the market absorbs news via order flows at the start and the end of trading. The study has implications for the design of efficient trading systems and emphasizes the need to study closely the relation between the price discovery period and the exchange regime available to participants at the open and the close of trading.

NOTES

1 Officially known as 'The International Stock Exchange, London'.
2 The relative sizes of the top three stock markets, as of December 1991, were New York (US$ 3484.4 billions), Tokyo and Osaka (US$ 311.37 billions) and London (US$ 974.6 billions) according to the Federation International des Bourses de Valuers (quoted in Niemayer and Sandas, 1993).
3 On the IDB, market makers can either post limit orders or trade anonymously against the IDB quotes of other market makers; these quotes are usually firm and better than those shown on the SEAQ screen.
4 Excellent descriptions of the London Stock Exchange microstructure are available in Board and Sutcliffe (1995) and Gemmill (1994).
5 Various other time intervals *viz.* 5-minute and also 30-minute were tried. Finer time intervals create a noisier data series without providing any additional information. Also, a longer time interval, say 30-minutes, masks some of the changes during the pre-MQP periods.
6 This follows the procedure in Chan et al. (1995).
7 That is, from SEAQ open till just after the MQP open and from the end of the MQP till the close of the SEAQ system.

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