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Thomas H. McInish; Robert A. Wood

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THOMAS H. MCINISH and ROBERT A. WOOD*

ABSTRACT

The behavior of time-weighted bid-ask spreads over the trading day are examined. The plot of minute-by-minute spreads versus time of day has a crude reverse *J*-shaped pattern. Schwartz identifies four determinants of spreads: activity, risk, information, and competition. Using a linear regression model, a significant relationship between these same factors and intraday spreads is demonstrated, but dummy variables for time of day have a reverse *J*-shape. For given values of the activity, risk, information and competition measures, spreads are higher at the beginning and end of the day relative to the interior period.

THIS STUDY HAS A dual focus. First, it extends prior work by examining whether variables previously found to be determinants of spreads using data for intervals of a day or longer also explain spreads during the trading day. Second, the paper furthers previous research concerning intraday patterns in returns, variability, and volume by examining intraday patterns of spreads.

Schwartz (1988, pp. 419–420) identifies four classes of variables as determinants of bid-ask spreads: activity, risk, information, and competition. Each of these determinants is considered briefly. Greater trading activity can lead to lower spreads due to economies of scale in trading costs. Using trading cost arguments, previous researchers show that a number of activity variables are significant determinants of bid-ask spreads including: (1) the average number of shares traded (Tinic, 1972), (2) the volume (Tinic and West (1972), Branch and Freed (1977), Stoll (1978)), and (3) the number of transactions (Benston and Hagerman, 1974). Copeland and Galai (1983) model the bid-ask spread as a free straddle option provided by the market maker and show that the bid-ask spread is inversely related to the frequency of trading. Copeland and Galai (1983) note that since less frequent trading usually means lower trading volume, the bid-ask spread is likely to be inversely related to measures of market activity. Inventory control models (Garman (1976), and Ho and Stoll (1980, 1981, 1983)) show that uncertainty in the arrival of buy and sell orders forces dealers away from their optimal inventory position. In the model of Amihud and Mendelson (1980), as the marker-maker approaches the desired inventory position the bid-ask spread is reduced. Hence, if greater

*McInish is the Wunderlich Chair of Excellence in Finance and Wood is a Distinguished Professor of Finance at Memphis State University in Tennessee. The authors wish to thank Yakov Amihud, Anat Admati, John Burke, Kalman Cohen, Joel Hasbrouck, Albert (Pete) Kyle, Larry Lockwood, and Keith Ord.

volume of trading or larger trade sizes move a dealer away from the desired inventory position, spreads will increase. If economies of scale predominate, then the following hypothesis would hold.

Hypothesis 1: *There is an inverse relationship between spreads and trading activity.*

Researchers examining trading costs find that a dealer's risk of holding a security is a significant determinant of the bid-ask spread; these researchers use measures of total risk (Tinic (1972), Tinic and West (1972), Branch and Freed (1977), Hamilton (1978), Stoll (1978)) and of systematic and unsystematic risk (Benston and Hagerman (1974), Stoll (1978)). Given these considerations, the following hypothesis would be expected to hold.

Hypothesis 2: *There is a direct relationship between the level of risk and spreads.*

Hasbrouck (1988) shows that the spread is related to the specialist's perceived exposure to private information so that "large trades convey more information than small trades." Glosten and Milgrom (1985) develop a model that deals with how spreads respond to market-generated and other public information. Since dealers perceive that there is a positive probability that orders originate from informed traders, orders convey information and affect quotations. Schwartz (1988) argues that "it is likely that the spread widens at times of substantial informational change." Hence, the following hypothesis is expected to hold.

Hypothesis 3: *There is a direct relationship between spreads and the amount of information coming to the market.*

A number of researchers using trading cost models have reported an inverse relationship between the level of competition and spreads (Demsetz (1968), Tinic and West (1972), Benston and Hagerman (1974), Hamilton (1976, 1978), and Branch and Freed (1977)). These considerations lead to the following hypothesis.

Hypothesis 4: *There is an inverse relationship between spreads and the level of competition.*

Turning next to the examination of intraday patterns, Wood, McInish, and Ord (1985), Harris (1986) and McInish and Wood (1990a) show that variability of returns exhibits a U-shaped pattern over the trading day. Volatility of returns is a direct measure of risk and an indirect measure of the level of information (French and Roll, 1986). Since risk is a determinant of spreads, U-shaped patterns in variability of returns suggest the possibility of U-shaped patterns in spreads with higher spreads at the beginning and end of the trading day. Further, Jain and Joh (1988) and McInish and Wood (1990b) report intraday U-shaped patterns in volume. Volume of trading is a direct measure of trading activity. It is also likely that competition will vary with volume. Specifically, the crowd is more active as volume levels rise. Hence, this factor suggests an inverted U-shaped pattern in spreads. Greater activity and competition at the beginning and end of the trading day suggests lower spreads at these times. Therefore, the joint effect of risk, information, activity and competition on intraday variability of spreads is indeterminant.

The remainder of this paper is divided into three sections. Section I describes the data and methodology. In Section II the results are presented. The final section provides conclusions.

I. Data and Methodology

A. Description and Preparation of the Data

The data for this study comprise every quotation (market bid and ask) for NYSE stocks entered into the Consolidated Quotation System by NYSE specialists for the first six months of calendar year 1989. The quotations were obtained from tapes provided by the Institute for the Study of Security Markets. These quotations reflect the specialist's own supply/demand, the crowd, and the book. Hence, these data reflect the strategic behavior of the specialists and other market participants. Each quotation is time stamped to the nearest second at the time it is provided to quotation vendors by the Securities Industry Automation Corporation rather than earlier in the quotation generation process. The length of time between the reporting of the quotation by the specialist and the Securities Industry Automation Corporation time stamp may vary slightly depending upon the trade and quote activity levels. Quotations that are not firm are not included in the sample. Quotations from regional exchanges and for stocks that trade at a price of less than $5.00 are excluded and stocks with fewer than 150 trades or fewer than 150 quotes for the calendar year are omitted. Stock were eliminated based on their characteristics for all of 1989 because the empirical tests were replicated using data for the last six months of 1989, but these results are not reported because they do not alter any of the conclusions.

During 1989, trading on the NYSE was conducted from 9:30 A.M. to 4:00 P.M. New York time. A minute-by-minute time series of time-weighted percentage bid-ask spreads over the trading day for the market is constructed. Also, for use in the regression analysis described below, the trading day is segmented into one 31-minute interval and twelve successive 30-minute intervals. The time-weighted bid-ask spread (BAS) for each security for each interval is then calculated. The determinants of these BASs are investigated. The way the BASs are calculated is explained with greater specificity below.

Quotations prior to the opening are excluded and no quotation is carried overnight. Quotations time stamped after the close are also excluded from the minute-by-minute analysis, but are included in the last thirty-minute interval of the trading day. The time-weighting is based on the number of seconds the quotation is outstanding during the one-minute or thirty-minute interval. While time-weighting seems to be the best approach for this study, it is recognized that the BASs do include spreads for some stale quotations that may not accurately reflect the current market.

After editing for errors,[1] a typical percentage bid-ask spread for each minute of the trading day is created. First, a time-series of second-by-second percentage bid-ask spreads is created for each stock. The time-series begins with the initial quotation each trading day. For a given stock for every second during which a quotation is outstanding a percentage bid-ask spread is calculated as (ask − bid)/((ask + bid)/2). The process is repeated for each stock. Then, for each trading second of the calendar year, all of the percentage bid-ask spreads are averaged to create a second-by-second time series of "market" percentage bid-ask spreads. The percentage bid-ask spreads are then averaged within each trading minute to create a time series of minute-by-minute bid-ask spreads.

A time-weighted BAS is then calculated for thirty-minute intervals for use in the analyses described below. A percentage bid-ask spread (BAS) is computed for every quotation as: BAS = [(ask − bid)/(ask + bid)/2]. Suppose that in the interval (T, T') there are N quotation updates, occurring at times t_i, $i = 1,\cdots, N$, with spreads BAS_i, $i = 1,\cdots, N$ where $t_0 = T$ and $t_{N+1} = T'$. BAS_0 is based upon the quotation that is outstanding at time T (i.e., the quotation outstanding at the beginning of the thirty-minute time interval). Note that since quotations from previous days are not used, BAS_0 does not exist prior to the first quotation of the day. The interval (T, T') is measured in seconds. For the interval during which the first quotation of the day occurs, the time-weighted spread is:

$$\sum_{i=1}^{N} \frac{\mathrm{BAS}_i(t_{i+1} - t_i)}{(T' - t_1)}$$

For intervals beginning subsequent to the first quotation of the day, the time-weighted spread is:

$$\sum_{i=0}^{N} \frac{\mathrm{BAS}_i(t_{i+1} - t_i)}{(T' - T)}$$

At least five sources of bias are potentially introduced by late initial quotations—weighting, sampling, delayed openings, quotation delay, and resolution of uncertainty.

1. Firms that are quoted earlier in the trading day will have a greater representation in the earlier minutes. Since (as shown below) these

[1] According to the Institute for the Study of Security Markets, the error-checking algorithm looks for a return with an absolute value greater than a limit that is a decreasing function of the price of the stock being filtered. Once a potential error is identified, the algorithm looks for reversals. For example, if a stock is trading at $40 per share and a price of $4 is observed, it is clearly an error. Up to five repetitions of the $4 price just described would be identified by the algorithm. The algorithm also examines the volatility of returns around the suspected error pattern before flagging the prices as erroneous. The higher the volatility, the less likely that the suspected prices would be flagged. Further, the relationship between trades and quotations around a suspected error is examined. Suspect prices or quotations are not dropped from the database, but simply multiplied by −1.

stocks have lower spreads, a downward bias is introduced in the early minute-by-minute averages across stocks. This bias exists to a much lesser extent in the thirty-minute analysis since most stocks will have been initially quoted in the first 31-minute interval.

2. Since stocks that are initially quoted during an interval will be reflected in only part of that interval, their sampling error for that interval will be larger than would have been the case if the quotation occurred earlier.
3. Delayed openings may result from uncertainty concerning the appropriate opening price which, in turn, will likely result in increased spreads.
4. Spreads for late initial quotations may be smaller than for earlier initial quotations since the uncertainty associated with equilibrium prices may have been resolved partially by the opening of other stocks by the time of the late quotation.
5. The stale quote problem (mentioned earlier) affects both initial intervals and subsequent intervals. If a specialist delays a quote revision after the arrival of new information, then the new information will have a smaller effect on that interval than if the quotation had been revised immediately. Stale quotations can obfuscate intraday patterns of a particular stock if quotations are revised quickly in some periods and slowly in others (e.g., when the specialist is busier). Also, stale quotations may affect comparisons across stocks if some specialists revise quotations more quickly than others.

All statistical tests are performed at the 0.01 level of significance unless otherwise indicated.

B. Methodology: Analysis of the Data by Interval

A linear regression model is used to test Hypotheses 1–4. In the regressions, BAS is regressed against a variety of independent variables. Since the distributions of the variables are highly skewed, the square roots of the variables are used so that outliers do not dominate the results.

Hypothesis 1 is tested using two activity variables. The first is the square root of the number of transactions in each issue i in Interval t ($\text{TRADES}_{i,t}$) and the second is the square root of the average number of shares per trade for each issue i in Interval t ($\text{SIZE}_{i,t}$). Because of economics of scale considerations, both TRADES and SIZE are expected to have an inverse relationship with bid-ask spread.

As mentioned, previous researchers have shown that a stock's risk is related to its spread (Hypothesis 2). Since previous studies of the determinants of spreads did not examine intraday spreads using transactions data, these studies typically used measures of total risk and systematic risk, but with transactions data a unique estimate of risk for very short intraday intervals can be estimated. These measures are more suitable for use in explaining the determinants of spreads during the trading day. Define $V_{i,t}$ as the standard deviation of the time-weighted average of the bid and ask for each stock i in Interval t, M_i as the mean of $V_{i,t}$ for stock i over all t and S_i as the standard deviation of $V_{i,t}$ for stock i over all t. The first measure of risk for stock i (RISK1_i) is M_i and the second measure of risk for stock i in Interval t ($\text{RISK2}_{i,t}$) is $(V_{i,t} - M_i)/S_i$. RISK1 captures differential risk from one stock to another and RISK2 (the normalized value of RISK1) captures differential risk from one interval to another for the stock.

As noted above, previous researchers have often used risk measures based on transaction prices such as systematic risk, unsystematic risk and total risk. But for the trade-to-trade data used here, measures of risk based on transaction prices are significantly affected by bid-ask bounce. Of course, bid-ask bounce is significantly affected by the size of the spread, the variable investigated in this study. Hence, trade-based measures of risk are not suitable for use in this study.[2] The risk measures used here are based on variability of the mid-point of bid and ask quotes and are not affected by bid-ask bounce. It seems reasonable to believe that this measure of variability reflects the risk faced by the specialist.

Schwartz (1988, p. 419) suggests that the effect of information on spreads could be tested by considering the effect of current trading volume on spreads while controlling for a stock's normal trading volume. Volume of trading was examined, but the results are not presented because an alternative variable proved superior for testing Hypothesis 3. Specifically, for each security, the mean (X_i) and standard deviation (D_i) of the square root of the volume per trade ($\text{SIZE}_{i,t}$) for stock i over all t are calculated. Then, for each security for each interval, the normalized value of the square root of the number of shares per trade for stock i in interval t ($\text{NSIZE}_{i,t}$) is calculated: $\text{NSIZE}_{i,t} = (\text{SIZE}_{i,t} - X_i)/D_i$. NSIZE is used as an explanatory variable. While SIZE captures scale economies associated with trade size, NSIZE captures the effect of unusually large or small trades relative to the average size of trades during a given interval for a given stock. Following the arguments of Hasbrouck (1988) periods during which there are relatively more unusually large trades are likely to have greater information flow. Alternately, unusually large trades may capture movement of dealers away from their preferred inventory position (Amihud and Mendelson, 1980).

A variable to test Hypothesis 4 is included next. The variable, $\text{REGIONAL}_{i,t}$, is the square root of the ratio of the number of shares of stock i traded on regional exchanges to the number of shares traded on the NYSE during interval t. This variable captures the extent of competition in the spirit of variables such as the of the number of dealers used by previous researchers. These previous measures of the level of competition such as the number of market makers or number of markets on which the stock is traded (Demsetz (1968), Tinic and West (1972), Benston and Hagerman (1974), Hamilton (1976, 1978), and Branch and Freed (1977)) are not suitable for use with transactions data because they do not change over the trading day. An inverse relationship between BAS and REGIONAL is expected.

[2] The authors thank an anonymous referee for this insight.

Several researchers (Demsetz (1968), Tinic (1972), Tinic and West (1972), Benston and Hagerman (1974), Hamilton (1976, 1978), and Stoll (1978)) show that there is an inverse relationship between a stock's price and its spread. Hence, in the regression model presented below, the square root of the average price in Interval t ($\mathrm{PRICE}_{i,t}$) is included as a control variable.

The linear model is:

$$\begin{aligned} \mathrm{BAS}_{i,t} = {} & b_0 + b_1\,\mathrm{TRADES}_{i,t} + b_2\,\mathrm{SIZE}_{i,t} + b_3\,\mathrm{RISK1}_i \\ & + b_4\,\mathrm{RISK2}_{i,t} + b_5\,\mathrm{NSIZE}_{i,t} + b_6\,\mathrm{REGIONAL}_{i,t} + b_7\,\mathrm{PRICE}_{i,t} \\ & + 12 \text{ Interval Dummy Variables (numbered 1–9 and 11–13)} \\ & + 4 \text{ Weekday Dummy Variables} + e_{i,t} \end{aligned} \tag{1}$$

where $\mathrm{BAS}_{i,t}$ is the time-weighted percentage bid-ask spread for stock i in Interval t, the remaining variables are as defined in this subsection, b_0, b_1, b_2, b_3, b_4, b_5, b_6, and b_7 (along with $b_8 - b_{23}$ for the interval and weekday dummy variables) are parameters to be estimated and $e_{i,t}$ is a random error term. Examination of variance inflation factors from SAS PROC REG for the above model indicates statistically significant multicollinearity (a variance inflation factor of 7). While this multicollinearity has undoubtedly reduced the t-statistics for some of the explanatory variables, it has not resulted in any sign reversals. Given the large sample size and the consistency of the results for each half of 1989, multicollinearity is not considered to have biased the test outcome.

If the relationship between BAS and the explanatory variables is assumed to be the same for each interval, then differences in the intercept can be captured through the use of dummy variables for intervals 1–9 and 11–13.

There are also four dummy variables that equal 1 if the observation occurs on a Monday, Tuesday, Thursday, or Friday, respectively, and 0 otherwise. These are designed to capture potential day-of-the-week effects identified by French (1980).

For a given stock for a given interval, if there are no observations of BAS or one of the explanatory variables, then that interval is deleted from the analysis.

II. Results

A. Minute-by-Minute Analysis

Examination of the mean BASs for each minute of the trading day presented in Figure 1 shows that spreads are relatively high at minute three, decline at a decreasing rate until minute 293 and then increase at an increasing rate until the close of trading. Thus, the plot of spreads over the trading day exhibits a crude reverse J-shaped pattern. The relatively low level of spreads for minutes 1–3 reflect the greater weight of thicker stock discussed in the previous section. Thicker stocks with smaller spreads are

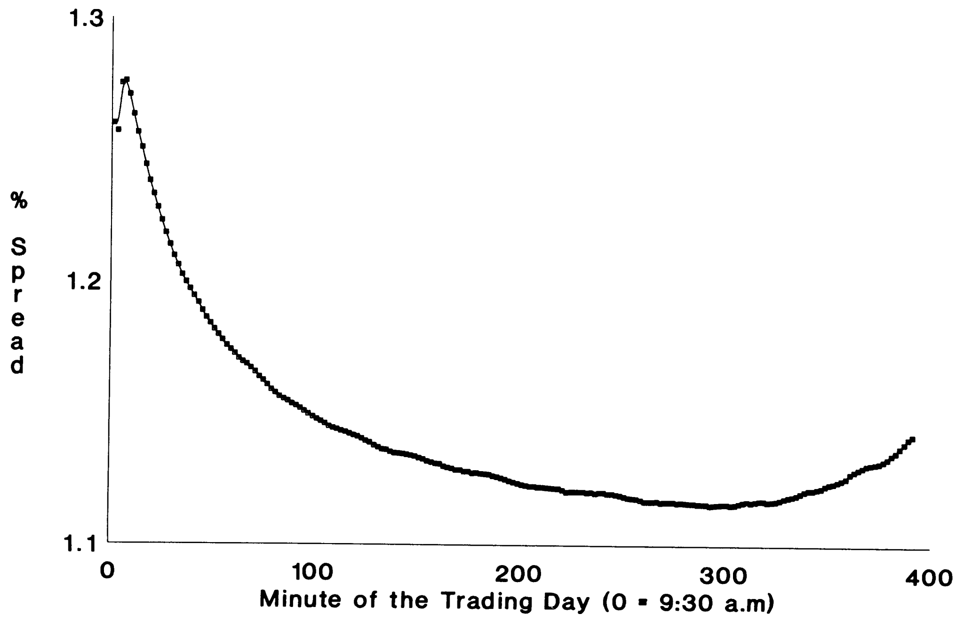

Figure 1. Mean Bid-Ask Spreads for Each Minute of the Trading Day. First, a time-series of second-by-second percentage bid-ask spreads is created for each stock. The time-series begins with the initial quotation each trading day. For a given stock for every second during which a quotation is outstanding a percentage bid-ask spread is calculated as (ask − bid)/((ask + bid)/2). The process is repeated for each stock. Then, for each trading second of the calendar year, all of the percentage bid-ask spreads are averaged to create a second-by-second time series of "market" percentage bid-ask spreads. The percentage bid-ask spreads are then averaged within each trading minute to create a time series of minute-by-minute bid-ask spreads.

opened first and therefore have greater weight relative to thinner stocks during the first few minutes compared with later in the trading day.

B. Interval Analysis

The results of the regression of BAS against the explanatory and dummy variables are presented in Table I. Recall that BAS is a percentage spread rather than a dollar-value spread. The coefficients of TRADES and SIZE are significantly negative confirming Hypothesis 1. The coefficient of RISK1 is significantly positive demonstrating that differential spreads across stocks can be explained in part by differences in a stock's risk. The coefficient of RISK2 is also significantly positive showing that spreads are larger during intervals with greater risk. Hence, these results are consistent with Hypothesis 2. The coefficient of NSIZE, the measure of information flow as reflected in trades of an unusual size, is significantly positive supporting Hypothesis 3. The coefficient of REGIONAL is significantly negative demonstrating that greater trading activity on the regional exchanges is associated with smaller spreads as stated in Hypothesis 4. As indicated below, the direction of

Table I

Results for the Regression of Percentage Spreads Against Activity, Risk, Information, Competition and Control Variables

Each trading day during the first six months of 1989 is segmented into one 31-minute interval and twelve thirty-minute intervals (9:30 A.M. to 10:00 A.M., etc). Then, for each security i for each interval t, the mean value of the following variables is calculated: (1) the time-weighted percentage bid-ask spread $\text{BAS}_{i,t}$, (2) the square root of the number of trades ($\text{TRADES}_{i,t}$), (3) the square root of the number of shares per trade ($\text{SIZE}_{i,t}$), (4) $\text{SIZE}_{i,t}$ minus the mean of $\text{SIZE}_{i,t}$ for stock i over all t and then divided by the standard deviation of $\text{SIZE}_{i,t}$ for stock i over all t ($\text{NSIZE}_{i,t}$), (5) the square root of the number of trades on regional exchanges relative to the number on the NYSE ($\text{REGIONAL}_{i,t}$), and (6) the square root of the average price ($\text{PRICE}_{i,t}$). Define $V_{i,t}$ as the standard deviation of the time-weighted average bid and ask for each stock in interval t, M_t as the mean of $V_{i,t}$ for stock i over all t and S_i as the standard deviation of $V_{i,t}$ for stock i over all t. The first measure of risk (RISK1_i) is M_i and the second measure of risk ($\text{RISK2}_{i,t}$) is $(V_{i,t} - M_i)/S_i$. $\text{BAS}_{i,t}$ is regressed against TRADES, SIZE, RISK1, RISK2, NSIZE, REGIONAL, and PRICE plus dummy variables for each of the 13 intervals (with interval 10 omitted) and dummy variables for each day of the week (with Wednesday omitted).

Independent Variables	Coefficients	t-statistic
INTERCEPT	0.0158	849.12[a]
TRADES	−0.0005	−226.96[a]
SIZE	−0.0002	−82.28[a]
RISK1	0.0668	320.45[a]
RISK2	0.0004	137.23[a]
NSIZE	0.0005	80.98[a]
REGIONAL	−0.0002	−24.66[a]
PRICE	−0.0018	−673.17[a]
Regression Results		
Interval 1	0.00065	49.12[a]
Interval 2	0.00042	32.35[a]
Interval 3	0.00030	23.46[a]
Interval 4	0.00021	16.09[a]
Interval 5	0.00016	11.97[a]
Interval 6	0.00009	6.58[a]
Interval 7	0.00001	0.05
Interval 8	−0.00005	−3.71[a]
Interval 9	−0.00038	−2.88[a]
Interval 11	0.00011	8.65[a]
Interval 12	0.00025	18.98[a]
Interval 13	0.00041	32.19[a]
Monday	0.00004	4.61[a]
Tuesday	0.00001	1.78
Thursday	0.00003	4.31[a]
Friday	0.00005	6.13[a]
R-square	0.4652	N = 871,954
F-statistic	32,983	

[a] Significant at the 0.01 level.

causality is uncertain. In addition, the control variable PRICE shows that higher priced stocks have smaller spreads.

The coefficients of the dummy variables for each interval of the trading day reveal a crude reverse *J*-shaped pattern strictly declining from Interval 1 to Interval 9 and then strictly increasing from Interval 11 to Interval 13. Hence, after controlling for the determinants of spreads used in this analysis, a reverse *J*-shape time-of-day component remains. It is possible that the time-of-day dummy variables are capturing a time-of-day preference for trading (i.e., structural changes in the trading process across the trading day). Alternately, a variable may be omitted. It is conjectured that a variable is omitted that is related to the resolution of risk over the trading day.

The coefficients of the dummy variables for each day of the week are all significantly positive indicating that there are differences in spreads by day of the week, but the levels of the t statistics indicates that weekday patterns are relatively weak compared with the strength of the intraday patterns. Moreover, the pattern is different than that reported in an earlier version of this paper for five months in 1987, so that the weekday pattern is not stable over time. Further, the regression analysis was repeated for the last six months of 1989, but the results are not shown because the conclusions are identical to those already presented—only the pattern of the weekday dummy variables changed.

III. Conclusions

This paper examines both the intraday behavior and the determinants of time-weighted percentage bid-ask spreads during the first six months of 1989. On a minute-by-minute basis, spreads are shown to have a crude reverse *J*-shaped pattern.

Previous research has shown that bid-ask spreads are determined by activity, risk, information, and competition. This paper extends previous work by using data for 13 intervals of the trading day to examine the determinants of spreads on an intraday basis. Using a linear regression model, bid-ask spreads for each interval are regressed against variables hypothesized to be determinants of spreads. The level of spreads is found to be significantly inversely related to two measures of activity, the number of trades and the number of shares per trade. The level of spreads is directly related to both differential risk across stocks and differential risk across intervals of the trading day. Intervals of the trading day during which there are trades of an unusually large size have higher spreads reflecting the information content of these trades. Greater competition from regional exchanges is associated with lower spreads. The direction of causality for the inverse relationship between NYSE spreads and regional trading volume is uncertain. Greater regional competition may reduce NYSE spreads, but tight NYSE spreads may result in great regional trading. Consider a Major Market Index basket crossed intraday to capture an arbitrage opportunity. The rule requiring a cross at a given price to clear out all limit orders on the book at that price or better may cause trades to migrate to the regional exchanges. Suppose that the NYSE quotation is 20 1/4 ask and that the size of the limit orders at this price is large while, say, the Pacific Exchange ask is 20 3/8. Then, a cross on the NYSE at 20 1/4 would require taking all the limit order shares off the book before executing the cross. But if the cross is executed on the Pacific Exchange where the ask of 20 3/8 indicates that there are no limit orders at 20 1/4, there is no interference from the limit order book.

The market microstructure literature has demonstrated that there are intraday patterns in returns (Wood, McInish, and Ord, 1985), variability of returns (Wood, McInish, and Ord (1985), McInish and Wood (1990a)), the volume of trading (Jain and Joh, 1988; McInish and Wood (1990b)), the number of trades and the number of shares per trade (McInish and Wood, 1991b), and daily index autocorrelations (McInish and Wood, 1991a). Hence, it seems reasonable to examine whether there are intraday patterns in bid-ask spreads.[3] Consequently, dummy variables for each interval of the trading day (except one) are incorporated into the linear regression model described in the previous paragraph. The coefficients of these dummy variables exhibit a reverse *J*-shaped pattern over the trading day. Spreads are higher at the beginning and end of the trading day than would be expected based on the values of the determinants of spreads at those times. This finding suggests the need to search for additional determinants of spreads that may be especially relevant for explaining intraday variability in spreads.[3]

While there are also differences in spreads across days of the week, the strength of these differences is much less than across intervals of the day. Further, there is evidence that the pattern of differences across days of the week is not stable over time.

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