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Market Structure and the Intraday Pattern of Bid-Ask Spreads for NASDAQ Securities*

This article examines the intraday pattern of bid-ask spreads among NASDAQ stocks. We find that spreads are relatively stable throughout the day but narrow significantly near the close. This contrasts with the U-shaped pattern for NYSE stocks reported by Brock and Kleidon and McInish and Wood. We attribute these divergent patterns to structural differences between specialist and dealer markets. The wider spreads for NYSE stocks near periods of market closure may reflect the market power of specialists. The decline in spreads near the close for NASDAQ stocks is consistent with inventory control by individual dealers.

I. Introduction

Several recent empirical studies examine the intraday pattern of bid-ask spreads in a market with a single specialist. Brock and Kleidon (1992), McInish and Wood (1992), and Lee, Mucklow, and Ready (1993) document that the intraday width of bid-ask spreads for New York Stock Exchange (NYSE) stocks follows a U-shaped pattern, where spreads are widest immediately after the open and immediately preceding the close. This article studies the intraday pat-

* We are grateful for the helpful comments of Gene Finn, Margaret Forster, Thomas George, Lawrence Harris, Donald Keim, Robert Korajczyk, Kelly McNamara, Harold Mulherin, Hans Stoll, René Stulz, Ingrid Werner, and seminar participants at the University of Iowa, Northwestern University, Ohio State University, and the 1993 Western Finance Association meetings. An anonymous referee provided valuable comments that significantly improved the manuscript. We are also indebted to Jeffrey Harris for his excellent research assistance. Christie acknowledges the financial support of the Dean's Fund for Faculty Research at the Owen Graduate School of Management and the Financial Markets Research Center at Vanderbilt University. Chan and Schultz acknowledge the financial support from the Dice Center for Financial Research at Ohio State University. All remaining errors are ours.

(*Journal of Business*, 1995, vol. 68, no. 1)

0021-9398/95/6801-0002$01.50

tern of bid-ask spreads for two samples of National Association of Securities Dealers Automated Quotation (NASDAQ) stocks and relates the results to the institutional features of the dealer market.[1] Our findings indicate that, in contrast to the U-shaped pattern for NYSE stocks, the bid-ask spread for NASDAQ securities is relatively stable throughout the day but narrows significantly during the final hour of trading. These results are similar to those of Kleidon and Werner (1993), who identify a pattern of declining intraday spreads for firms on the London Stock Exchange during mandatory trading hours. The London stock market, like NASDAQ, is structured as a multiple dealer system. Thus, the difference in intraday patterns between the NYSE and either the NASDAQ or the London market supports the contention that the institutional features of markets can have material effects on the determination of spreads over the day.

Various models have been proposed to explain the intraday pattern of bid-ask spreads for NYSE stocks. Some models link the wider than average spreads at the open and close to the market power of a single specialist. For example, Stoll and Whaley (1990) find support for the hypothesis that the wider spreads at the open reflect the specialists' ability to profit from their privileged knowledge of the order imbalances. Brock and Kleidon (1992) develop a model of intraday spreads where specialists possess monopoly power and exercise it to exploit the inelastic demand of investors to trade around the open and close by widening bid-ask quotes. Other models attribute intraday spreads to variation in the costs of adverse selection. For example, Madhavan (1992) considers traders with diverse information concerning the value of an asset at the onset of trading. As trading continues, private information is impounded into prices, and specialists narrow their spreads as their informational handicap declines. Admati and Pfleiderer (1988) model the strategic decisions of liquidity traders who have discretion over the timing of their trades. By concentrating their trades in specific periods, discretionary liquidity traders minimize the adverse selection costs facing specialists, leading to the simultaneous occurrence of heavy trading volume and narrow spreads at specific times during the day.

The relative importance of market structure versus information-based factors in determining the intraday pattern of bid-ask spreads can be gauged by comparing the results for NYSE versus NASDAQ stocks. The distinction between these spread determinants is that the

1. This article focuses on the intraday patterns of bid-ask spreads for stocks that trade in a dealer market, rather than on the differences in trading costs across market structures. Examples of the latter include Blume and Goldstein (1992), Christie and Huang (1994), Christie and Schultz (1994), Goldstein (1993), Lee (1993), Neal (1992), and Petersen and Fialkowski (1992).

flow of information may be similar for NYSE and NASDAQ stocks, but the institutional structures of the markets are dissimilar. The primary institutional differences between markets include (1) a single specialist on the organized exchanges versus multiple dealers on the NASDAQ, (2) a call market open on the organized exchanges versus a quote-driven system that searches for equilibrium prices in a dealer market, and (3) the consolidation of order flow through the specialist versus the fragmentation of order flow across dealers.[2] We focus on the trading periods surrounding the open and the close since the structural differences across markets are most pronounced around market closures.

Although NYSE and NASDAQ spreads are widest immediately after the open, we find that NASDAQ spreads remain relatively constant during the first hour of trading. In contrast, NYSE spreads decline rapidly during the same time period. Under the assumption that information arrival is similar for firms that trade in these two markets, the differences in spreads subsequent to the open may reflect structural rather than information differences across markets. One such difference, as suggested by Brock and Kleidon (1992), is that the NYSE specialists' ability to exploit their market power may decline rapidly after the open as investors' demand to trade becomes more elastic. In contrast, individual NASDAQ dealers may find it difficult to exploit intraday changes in the elasticity of investors' desire to trade.[3]

A second institutional difference is that NASDAQ market makers are not afforded a formal mechanism for price discovery. Individual dealers, each facing a fraction of the total order flow, are forced to post quotes without knowledge of the propensity of investors to trade at the stated prices. Our evidence suggests that equilibrium prices are revealed through a large number of relatively small trades immediately after the open and that dealers are unwilling to commit to large trades during this period of price discovery.

The most striking difference between the intraday spreads of NYSE and NASDAQ stocks is that the spreads of NYSE stocks widen near the close while NASDAQ spreads narrow during the final 30 minutes of trading. Brock and Kleidon (1992) suggest that specialists can exploit their market power and the public's inelastic demand to trade near the close by widening spreads. If NASDAQ dealers lack the ability to

2. Although individual dealers can observe interdealer trades, they are unable to observe the trades between other market makers and their respective retail customers.

3. However, a multiple dealer market does not imply that dealers are without market power. Christie and Schultz (1994) find an almost complete absence of odd-eighth quotes for the majority of a sample of 100 actively traded NASDAQ stocks in 1991. They interpret this lack of odd-eighth quotes as evidence that dealers implicitly collude to maintain spreads of at least $0.25 by restricting quotes to even-eighths.

exploit the public's inelastic demand to trade at the close, the Brock and Kleidon model highlights a difference in market structure that may explain the divergence in the width of inside spreads near the close across markets. However, their model cannot explain the narrowing of spreads for NASDAQ stocks.

A more promising explanation for the difference between NYSE and NASDAQ spreads near the close arises from the control of inventory through bid and ask prices. Inventory effects are particularly important near the close as NYSE specialists and individual NASDAQ dealers face increased risks in holding unwanted inventory overnight. NASDAQ dealers with long positions may lower their bid and ask quotes to divert orders away from other dealers, while short positions dictate an increase in bid and ask prices. These actions can lead individual dealers to post quotes that narrow the inside spread, thereby reducing the percentage of dealers at the inside. Amihud and Mendelson (1982) develop an inventory model for dealers in a specialist market, where specialists respond to inventory imbalances by widening their spreads. If inventory imbalances accumulate during the course of trading, these imbalances may be particularly severe near the close. Thus, the widening (narrowing) of spreads for NYSE (NASDAQ) stocks may reflect the use of prices to control inventory.

However, NYSE specialists and NASDAQ market makers may differ in their ability to manage inventory using their bid and ask quotes. The affirmative obligation of specialists to maintain a fair and orderly market prevents them from executing orders on only one side of the spread. This regulatory requirement may constrain their ability to manage inventory using prices over the short run. In contrast, we provide evidence that individual market makers rarely post quotes that place them on both sides of the inside spread and that dealers move between the inside bid and inside ask more than once per day. Thus, NASDAQ dealers can set bid and ask quotes to attract trades on only one side of the spread and limit their exposure to trades that would aggravate unwanted inventory positions, enhancing their ability to control inventory through prices.

This article is organized as follows. Section II outlines the major institutional differences between market structures and discusses their implications for the width of bid-ask spreads near periods of market closure. Section III describes our data, while Section IV outlines the testing procedures. Section V establishes the intraday patterns in bid-ask spreads, and Section VI relates these results to the intraday levels of volume and volatility. Section VII appeals to the institutional features of the dealer market to explain the intraday width of bid-ask spreads. Section VIII contains a summary and offers concluding remarks.

II. Institutional Differences between the NYSE and NASDAQ

A. Differences in the Intraday Market Power of NYSE Specialists and NASDAQ Dealers

NASDAQ dealers face relatively constant competition for order flow throughout the day from the posting of bid and ask prices by other market makers. On the organized exchanges, specialists face competition from floor traders, priority rules that give precedence to public orders, and limit orders that establish prices against which others can trade. However, specialists have an informational advantage over other traders near the open and close of trading that is not shared by NASDAQ market makers.

In determining the opening price for NYSE stocks, the Opening Automated Report Service automatically matches buy and sell orders. The specialist then offsets any remaining order imbalance from inventory. Thus, the specialist uses knowledge of market and limit orders in setting the opening price.[4] Stoll and Whaley (1990) conclude that the ability of the specialist to set a low (high) bid (ask) price when the opening order imbalance requires purchases (sales) from inventory results in monopoly profits and excess volatility.[5] In contrast, no formal opening procedure is available on NASDAQ. The search for an equilibrium price may force dealers to post wider intraday spreads near the open as protection against the expected losses from facing informed traders, and/or to trade in relatively small units until equilibrium prices are determined.

The specialist is also afforded an opportunity to learn of the market's desire to trade through the "market-on-close" orders (i.e., orders that are to be executed as close to 4:00 P.M. as possible) that are routed to the specialist. This privileged knowledge may allow specialists to use their market power to widen spreads. In addition, Brock and Kleidon (1992) suggest that the market power afforded specialists through their knowledge of the order flow around periods of market closure may be enhanced as the demand to trade of investors is more inelastic at these times. Investors who attempt to maintain optimal portfolio holdings may be especially eager to trade at the open (to adjust portfolio imbalances arising from the arrival of new information during the nontrading interval) and at the close (to reestablish optimal overnight portfolio holdings, perhaps due to the differences in the variability of returns during the nontrading vs. the trading interval; see French and Roll

4. The NYSE order flow can also be observed by floor traders congregating at the post. In the case of large order imbalances, indicative quotes must be disseminated.

5. In contrast, Forster and George (1993) suggest that the transitory volatility associated with the opening results from compensation to the specialist for handling large order imbalances.

1986). This inelastic demand also emerges when brokers, who have discretion to time their trades, become increasingly willing to trade near the close. Fund managers may also prefer to trade at the end of the day as sales and redemptions of mutual fund shares are typically based on net asset value per share at the close. If the increased width of inside spreads at the open and close in a specialist market reflects the exploitation of the inelastic demand of investors to trade, replacing the specialist with multiple market makers would reduce the tendency of bid-ask spreads to widen near nontrading intervals.

B. Inventory Management

Inventory management by specialists and market makers may affect the width of bid-ask spreads near the close. As Hasbrouck and Sofianos (1992, p. 9) note, "The traders' admonition to 'go home flat' clearly bespeaks a distaste for large unhedged positions at the end of the trading day." Amihud and Mendelson (1982) predict that when a single dealer's inventory position deteriorates through trading, the width of the bid-ask spread increases to discourage additional accumulation.[6] In contrast, individual NASDAQ dealers who accumulate excess inventory may post bid or ask quotes to attract orders that otherwise would have been directed to competing dealers, thereby narrowing the inside spread.

Recent empirical work by Hasbrouck and Sofianos (1993) and Madhavan and Smidt (1993) suggests that although specialists' inventories are stationary, inventory imbalances are reversed over a number of trading days. Thus, specialists appear to require more than a single trading day to control inventory through prices. One possible reason for the slow reversal of inventory positions is that specialists are required to maintain an orderly market by standing ready to accept trades on both sides of the spread.[7] In contrast, NASDAQ market makers are not as tightly regulated and are under no such obligation. Individual dealers can elect to post bids and offers that either match or lie away from the inside quotes. Thus, the dealer market may pro-

6. An alternative explanation for the wider spreads near the close for NYSE stocks is related to the depth of the limit order book. Harris and Hasbrouck (1992) report that 82% of all limit orders are classified as day orders and are canceled at the close if unexecuted. If the depth of the limit order book is sufficiently shallow at the close, the inside spread can widen since the bid and/or ask reflects the specialists' quotes rather than those of the limit order book. If the specialists' quotes become exposed to the market, trading on their own account could further aggravate an inventory imbalance, forcing them to respond by widening their spread.

7. Although specialists must maintain a continuous presence in the market, their bid and ask quotes are often inferior to those in the limit order book. Thus, specialists are not continuously required to buy and sell from their own inventory. However, when limit order books are thin, specialists must be prepared to service the order flow from their personal accounts.

vide market makers with a more effective mechanism to control inventory through prices than specialists enjoy on the organized exchanges.

III. Data

Our data consist of trades and individual dealer quote revisions for two samples of NASDAQ stocks. The first sample includes 17 firms for the 39 days from October 14, 1991, through December 6, 1991, and the second includes 18 stocks for the 28 days from August 11, 1992, through September 18, 1992. We sample different firms from two nonoverlapping intervals to ensure that our inferences are not specific to one sample or time period. Firms are randomly selected from stocks that would have resided in the four largest size deciles of NYSE/AMEX (American Stock Exchange) stocks at the end of 1991. Our ability to attribute differences in volume, volatility, or bid-ask spreads to institutional rather than firm-specific factors is enhanced by only including stocks that are large enough for NYSE listing. Size deciles are computed using prices and outstanding shares from the Center for Research in Securities Prices (CRSP).

Table 1 lists the stocks that are included in our two samples. Twelve

TABLE 1 The NASDAQ Stocks Included in the 1991 and 1992 Samples

Firm	Ticker Symbol	Sample Period	NYSE/AMEX Decile
Apple Computer	AAPL	1991, 1992	10
Adobe Systems	ADBE	1992	10
Aldus Corp	ALDC	1991, 1992	9
Applied Material	AMAT	1992	9
Andrew Corp	ANDW	1991, 1992	8
Biomet	BMET	1991	10
Charming Shoppes	CHRS	1991, 1992	10
DSC Communications	DIGI	1992	7
Egghead Inc.	EGGS	1992	8
El Paso Electric	ELPA	1991	7
Electronic Arts	ERTS	1991, 1992	8
First Security	FSCO	1991, 1992	9
Lotus Development	LOTS	1991	10
MCI Communications	MCIC	1991	10
Microcom	MNPI	1991, 1992	7
Molex	MOLX	1991	10
Nellcor	NELL	1992	9
Sonoco Products	SONO	1991, 1992	10
Software Publishing	SPCO	1991, 1992	7
System Software	SSAX	1991, 1992	9
Sun Microsystems	SUNW	1992	10
Worthington Ind.	WTHG	1991, 1992	10
Yellow Freight	YELL	1991, 1992	9

NOTE.—Size deciles are computed from the market capitalization decile for New York (NYSE) or American (AMEX) stock exchange stocks measured at the end of 1991.

stocks are common to both 1991 and 1992. Five additional stocks are included in the 1991 sample and six additional stocks are included in 1992. The last column of the table provides the market capitalization decile that the stocks would have occupied had they been listed on the NYSE or AMEX at the end of 1991. The samples contain a substantial fraction of large firms, with eight of the 17 stocks in the 1991 sample and six of the 18 stocks in the 1992 sample qualifying for inclusion in the largest decile of listed stocks at the end of 1991.

Intraday trade and individual dealer quotes are obtained by downloading screens of real-time data from the Bridge Quotation System. Trade data consist of volume and prices, although the identity of the dealer executing the trade is unknown. Quote data consist of the bid and the ask identified by market maker for all quotes posted throughout the day and include the prevailing inside quote. Quotes and trades are time-stamped to the minute.

Descriptive statistics for our two samples are provided in table 2. The time-series means for each variable are calculated using 5-minute intervals for each stock. Table 2 summarizes the cross-sectional distribution of the individual means across stocks. Panel A presents the results for the 1991 sample. The median dealer spread is \$0.90 and ranges from \$0.52 to \$1.11. The median inside spread is \$0.33, with at least 75% of the firms in our sample quoted with an average inside spread of at least \$0.25. Interestingly, dealer spreads are more than twice as large as the inside spreads for each of the quartiles. The median percentage inside spread is 1.26% and ranges from 0.58% to 3.77%. Finally, the median number of dealers per stock averages 22.1 and ranges from 9 to 45.2, with the majority of dealers posting noncompetitive quotes (i.e., away from the inside) at any given time, as the average number of dealers at the inside bid or ask is 5.2, respectively.[8]

Table 2 also provides the cross-sectional distribution of quote changes, share volume, and the number of trades measured over 5-minute intervals. The median firm averages .81 market-maker quote revisions per interval, with the range extending from .22 to 5.7. The median share volume is 2,178 shares, with individual values ranging from 382 to 19,259 shares. Finally, the average number of trades per interval varies between .22 and 10.19.

Panel B of Table 2 reports descriptive statistics for the 1992 sample. A comparison of panels A and B indicates that the characteristics of the two samples are similar, although the average inside spread and

8. Although a minority of dealers post quotes at the inside, other dealers may still trade. Dealers who precommit to accepting preferenced orders must execute trades preferenced to them at the inside quote. In addition, by posting quotes away from the inside, dealers retain the option to trade while avoiding the 20-day delay required to reinitiate trading should they cease making a market.

TABLE 2 The Cross-sectional Distribution of Spread and Activity Variables for the Two Samples of NASDAQ Stocks

	Price, in $	Dealer Spread, in $	Inside Spread		Number of:			Activity (per 5 Minutes)		
			in $	in %	Market Makers	Inside Bid Quotes	Inside Ask Quotes	Quote Changes	Volume	Trades
A. 17 firms from October 14 through December 6, 1991:										
Maximum	51.72	1.11	.60	3.77	45.2	9.3	9.5	5.70	19,259	10.19
75th percentile	31.91	1.00	.43	1.79	35.4	6.2	6.4	1.97	3,984	1.67
Median	27.28	.90	.33	1.26	22.1	4.5	4.7	.81	2,178	1.15
25th percentile	22.60	.71	.27	.94	18.8	3.7	3.8	.39	1,354	.53
Minimum	4.95	.52	.18	.58	9.0	2.6	3.1	.22	382	.22
Mean	27.53	.87	.36	1.56	26.9	5.2	5.2	1.50	4,700	2.23
B. 18 firms from August 11 through September 18, 1992:										
Maximum	45.94	1.12	.62	6.04	51.8	9.2	10.8	3.85	18,186	8.88
75th percentile	30.60	1.00	.42	2.11	36.2	6.7	6.6	1.68	7,603	2.73
Median	25.26	.97	.35	1.45	28.4	5.5	5.5	.76	2,478	1.14
25th percentile	22.76	.72	.25	1.07	20.9	4.6	4.8	.25	1,125	.54
Minimum	3.69	.54	.16	.64	11.4	3.5	3.4	.09	496	.19
Mean	24.54	.88	.35	1.96	29.9	5.6	5.8	1.10	4,524	2.15

NOTE.—For each firm, the sample mean is calculated for each variable using values at the end of each 5-minute period. The table presents the distribution of the means across stocks in each sample. Dealer spreads are computed as the difference between the average ask and average bid for all dealers. The inside spread measures the difference between the inside ask and inside bid. The number of market makers is computed using information from the Center for Research in Security Prices daily master file. The number of inside bid and inside ask quotes denotes the number of market makers posting inside bid and ask prices at the end of each 5-minute interval. The number of quote changes, volume, and trades are averages summed within each 5-minute interval.

the number of market makers are higher in 1992. However, direct comparisons are difficult to make as only 12 firms are common to the two samples.[9]

IV. Testing Framework

Our approach closely follows Foster and Viswanathan (1993) in their study of intraday volume, volatility, and trading costs for NYSE securities. We test for intraday variation in spreads, volume, volatility, and other variables using Hansen's (1982) generalized methods of moments (GMM) procedure. Since our approach uses all time-series and cross-sectional observations to estimate one set of coefficients, we allow for arbitrary patterns of cross-sectional correlation, autocorrelation, and heteroscedasticity in calculating the asymptotic covariance matrix.

We first standardize the variables by dividing each observation by the time-series mean for the corresponding firm. We then estimate the following model for each standardized variable using all observations for all stocks

$$V_{i,t} = \alpha_0 + \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + e_{i,t},$$

where $V_{i,t}$ is the variable whose intraday variation is being examined for each stock i during time interval t. Given the quantity of intraday trades and quote revisions, our GMM estimates use 30-minute time intervals. The GMM estimates are computed using dummy variables that correspond to the following periods:

D_1 = 1 if the observation lies between 9:31 A.M. and 10:00 A.M., 0 otherwise;
D_2 = 1 if the observation lies between 10:01 A.M. and 11:00 A.M., 0 otherwise;
D_3 = 1 if the observation lies between 2:31 P.M. and 3:30 P.M., 0 otherwise; and
D_4 = 1 if the observation lies between 3:31 P.M. and 4:00 P.M., 0 otherwise.

This approach focuses on differences between the 11:01 A.M. to 2:30 P.M. midday period and the trading periods surrounding the open and close.

The GMM estimation involves selecting the vector of coefficient

9. The NASDAQ market was also more volatile during the 1991 sample period. Specifically, the standard deviation of daily returns for the CRSP value-weighted NASDAQ index is 1.1% for the 1991 period and 0.7% for the 1992 period. This difference can be partially attributed to a market break on November 15, 1991, when the index return was −4.39%. However, removing this date has no qualitative effect on our subsequent empirical results.

estimates, $\hat{\alpha}$, to minimize a weighted sum of sample moments. We estimate five sample moments for each stock, or 85 (90) moments for the 1991 (1992) sample. Thus, for the 17 firms in the 1991 sample, the vector of sample moments, $g_T(\hat{\alpha})$, is given by

$$g_T(\hat{\alpha}) = \frac{1}{T}\sum_{t=1}^{T}\begin{bmatrix} e_{1,t} \\ D_1 e_{1,t} \\ D_2 e_{1,t} \\ D_3 e_{1,t} \\ D_4 e_{1,t} \\ \vdots \\ e_{17,t} \\ D_1 e_{17,t} \\ D_2 e_{17,t} \\ D_3 e_{17,t} \\ D_4 e_{17,t} \end{bmatrix},$$

where T is the number of time-series observations. Our estimate of α is obtained by minimizing $g_T' W g_T$, where the weighting matrix, W, is a consistent estimator of the inverse of the asymptotic covariance matrix of $\sqrt{T}\, g_T(\hat{\alpha})$ after adjusting for serial correlation (up to 12 lags) as suggested by Newey and West (1987).

To test for significance of the $\hat{\alpha}$ coefficients, we rely on their asymptotic distribution

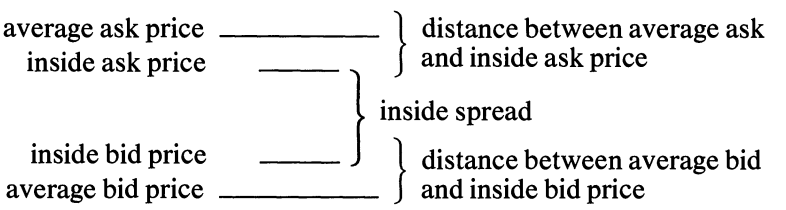
$$\sqrt{T}\,(\hat{\alpha} - \alpha) \sim N(0, [\delta_T' W \delta_T]^{-1}),$$

where δ_T is computed as

$$\frac{\partial g_T(\hat{\alpha})}{\partial \hat{\alpha}}.$$

V. Intraday Bid-Ask Spreads for NASDAQ Stocks

The relation between the inside spread and the dispersion of individual dealer quotes around the inside is examined within this framework:



We define the average difference of the n individual dealer quotes from the inside bid and inside ask quotes at the end of each 5-minute interval as biddif_t and askdif_t:

$$\text{biddif}_t = \sum_{i=1}^{n} \frac{\text{inside bid}_t - \text{bid}(i)_t}{n}$$

and

$$\text{askdif}_t = \sum_{i=1}^{n} \frac{\text{ask}(i)_t - \text{inside ask}_t}{n},$$

where $\text{bid}(i)_t$ and $\text{ask}(i)_t$ are the bid and ask quote for dealer i nearest the end of each 5-minute interval t. The average spread across all dealers at the end of each 5-minute interval t, defined as avespread_t, measures the distance between the average bid and ask and is computed as

$$\text{avespread}_t = \text{inside ask}_t - \text{inside bid}_t + \text{biddif}_t + \text{askdif}_t.$$

The percentage inside spread at the end of each 5-minute interval t is defined as

$$\text{PCT}_t = \frac{\text{inside ask}_t - \text{inside bid}_t}{\left(\frac{\text{inside ask}_t + \text{inside bid}_t}{2}\right)}.$$

Consistent with McInish and Wood (1992), quotes that are time-stamped at the open (i.e., 9:30 A.M.) are eliminated since they do not reflect quote revisions.

The GMM results are presented in tabular form for each of the two samples. We also consolidate the two samples and present the combined results graphically for the finer 5-minute intervals. The tables are intended to permit a direct comparison of the results for the two samples and to provide statistical measures of the intraday differences. The graphs allow a visual interpretation of our results for the combined samples.

Figure 1 plots the intraday patterns for the percentage inside spread and the percentage dealer spread. The figure indicates that the inside spread is widest after the open and remains relatively constant during the first hour of trading. The spread then declines steadily through noon, where it remains stable until narrowing abruptly during the last hour of trading. Table 3 formally tests for the intraday variation in the width of the inside spread, among other variables. The coefficients are interpreted as follows. The estimate of 0.974 for the percentage inside spread during the final 30 minutes of trading in panel A indicates that the percentage inside spread was 97.4% of the intraday average. A comparison of panels A and B indicates that the width of the inside

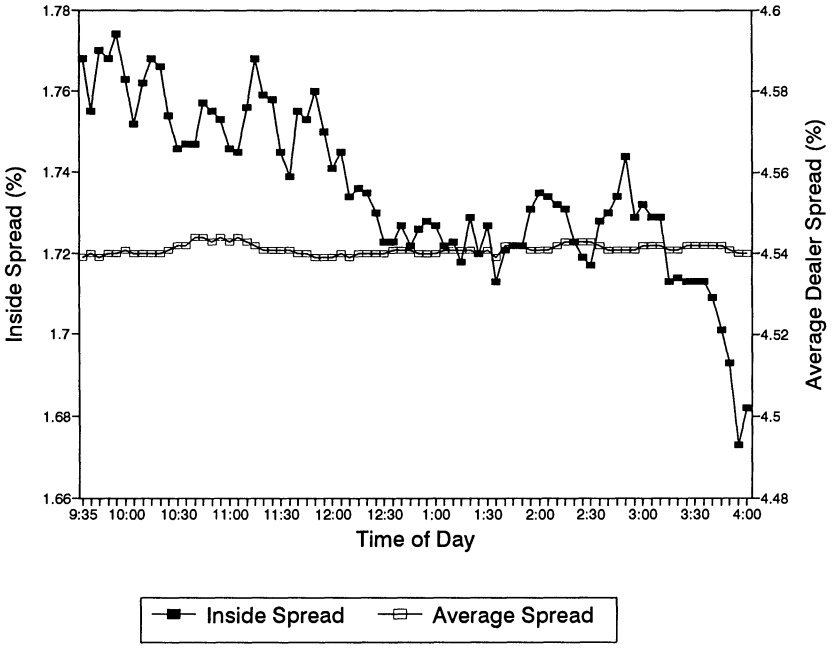


FIG. 1.—The intraday variation of percentage inside spreads and percentage average dealer spreads. The percentage inside spread and the percentage average dealer spread are computed using the average of the inside bid and inside ask prices at the end of each 5-minute interval. The data use all quotes for both the 1991 and 1992 samples.

spread declines by approximately 2.5% during the final 30 minutes of trading relative to its midday levels for both samples. The *t*-statistics confirm the statistical significance of these estimates. A comparison of the results across samples shows that the wider than average spreads during the morning shown in figure 1 can be attributed to the 1992 results, as the intraday spreads for the 1991 sample are only significantly different from the noonday period at the close.

Figure 1 also shows virtually no intraday variation in the average dealer spread.[10] This result is particularly striking given the marked decline in the inside spread during the afternoon, especially near the close. Thus, the decline in the inside spread reflects changes in the location rather than in the width of individual dealer quotes.

The intraday pattern of bid-ask spreads for our samples of NASDAQ stocks differs from the pattern for NYSE stocks where the width of

10. The estimates of the statistical difference in average dealer spreads across time intervals (not shown) confirm the inference that average dealer spreads are constant throughout the day.

TABLE 3 **Generalized Method of Moments (GMM) Estimates of Intraday Differences in Percentage Inside Spreads, the Number of Quote Revisions, and the Percentage of Dealers at the Inside Bid and Inside Ask**

Time Interval	Regression Coefficient	Percentage Inside Spreads	Number of Quote Revisions	Percentage of Dealers at the Inside Bid	Percentage of Dealers at the Inside Ask
A. 1991 (i.e., 17 firms for 39 days):					
9:31 A.M. to 10:00 A.M.	$\alpha_0 + \alpha_1$	1.002	1.975	1.015	1.000
		(−.34)	(32.09)	(.27)	(−.96)
10:01 A.M. to 11:00 A.M.	$\alpha_0 + \alpha_2$	1.003	1.111	1.010	1.004
		(−.23)	(10.93)	(−.12)	(−.65)
11:01 A.M. to 2:30 P.M.	α_0	1.004	.790	1.011	1.011
2:31 P.M. to 3:30 P.M.	$\alpha_0 + \alpha_3$	.996	.885	.959	.988
		(−1.52)	(2.45)	(−4.23)	(−2.23)
3:31 P.M. to 4:00 P.M.	$\alpha_0 + \alpha_4$	.974	1.166	.938	.958
		(−5.67)	(9.86)	(−6.23)	(−5.21)

B. 1992 (i.e., 18 firms for 28 days):					
9:31 A.M. to 10:00 A.M.	$\alpha_0 + \alpha_1$	1.011	1.868	1.044	.988
		(2.16)	(41.23)	(5.84)	(−.80)
10:01 A.M. to 11:00 A.M.	$\alpha_0 + \alpha_2$	1.012	1.201	1.018	1.000
		(2.40)	(14.21)	(3.49)	(.94)
11:01 A.M. to 2:30 P.M.	α_0	1.000	.797	.982	.995
2:31 P.M. to 3:30 P.M.	$\alpha_0 + \alpha_3$	.985	.946	.983	.969
		(−2.93)	(5.90)	(.07)	(−3.00)
3:31 P.M. to 4:00 P.M.	$\alpha_0 + \alpha_4$	.976	1.202	.948	.976
		(−3.70)	(14.89)	(−3.63)	(−2.34)

NOTE.—*t*-statistics are in parentheses. The inside spread is defined as the difference between the inside ask and the inside bid at the end of each 5-minute time interval. The average inside spread computed across all stocks and all 30-minute time intervals is 1.56% in 1991 and 1.96% in 1992. The number of quote revisions are summed within each 5-minute time interval. The average number of quote revisions per 30-minute time interval computed across all stocks is 9.0 in 1991 and 6.6 in 1992. The percentage of dealers at the inside bid is established at the end of each 5-minute interval. The percentage is then averaged across days for each firm during each 5-minute time interval. The average for each 30-minute time interval computed across all stocks is 19.3% in 1991 and 18.7% in 1992. The percentage of dealers at the inside ask is established at the end of each 5-minute interval. The percentage is then averaged across days for each firm during each 5-minute time interval. The average for each 30-minute time interval computed across all stocks is 19.3% in 1991 and 19.4% in 1992. Each series is standardized by dividing the individual values by the time-series mean for the corresponding firm. This averaging process produces variables with a mean of 1.0 for each firm. Tests for intraday variation are based on estimates obtained from the following model.

$$V_{i,t} = \alpha_0 + \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + e_{i,t},$$

where $V_{i,t}$ is the average for stock i during the 30-minute time period t, $D_1 = 1$ if the time is between 9:31 A.M. and 10:00 A.M., 0 otherwise; $D_2 = 1$ if the time is between 10:01 A.M. and 11:00 A.M., 0 otherwise; $D_3 = 1$ if the time is between 2:31 P.M. and 3:30 P.M., 0 otherwise; and $D_4 = 1$ if the time is between 3:31 P.M. and 4:00 P.M., 0 otherwise. The model is estimated from the pooled time-series and cross-sectional data using GMM with a Newey-West adjustment for serial correlation. An estimate of 1.5, for example, signifies that the value is 50% higher than the intraday average. The *t*-statistics test for differences between the 11:01 A.M. to 2:30 P.M. period and each of the other four periods.

the bid-ask spread is widest near the open *and* the close.[11] The inference that these dissimilar patterns arise from structural differences across markets is strengthened by recent empirical evidence by Kleidon and Werner (1993). They identify a similar pattern of declining intraday spreads for London Stock Exchange stocks during mandatory trading hours. Since the London market is structured as a multiple dealer system, the similarity between our results and theirs supports the contention that the organization of a market can have material effects on the determination of intraday spreads.

However, before attributing the intraday differences in the width of bid-ask spreads between NYSE and NASDAQ stocks to differences in market structure, we must first establish whether the intraday patterns in volume and volatility differ across markets.

VI. Intraday Patterns in Volume and Volatility for NASDAQ Stocks

Wood, McInish, and Ord (1985) and Harris (1986) find that, for broad-based samples of NYSE stocks, the variance of returns is much higher at both the open and the close than for the rest of the day. Jain and Joh (1988) study hourly aggregate NYSE volume and report that volume is particularly high at the beginning and toward the close of trading. Foster and Viswanathan (1993) and Brock and Kleidon (1992) also identify U-shaped patterns in volume and volatility for NYSE stocks. Thus, the intraday pattern of bid-ask spreads for NYSE stocks is mirrored by the intraday patterns in volume and volatility. This section tests whether similar inferences apply to our NASDAQ samples.

To estimate the intraday patterns in volatility, returns are calculated using the average of the inside bid and inside ask quotes at the end of each 5-minute interval, excluding overnight returns. The use of inside quote midpoints rather than trade prices alleviates spurious volatility induced by prices that alternate between the bid and the ask. Since this formulation ignores an expected return during any given 5-minute interval, the variance is computed as the average of squared returns. Figure 2 graphs the standard deviation of returns (representing averages computed across all stocks) during successive 5-minute intervals. The figure reveals the presence of high volatility immediately after the open and a subsequent decline during the following hour. In addition, volatility shows a tendency to rise near the close, though this increase is small relative to the levels observed near the open. Thus, the difference in bid-ask spreads for NASDAQ versus NYSE stocks near the

11. The reduction in the width of the spread for NASDAQ stocks relative to NYSE securities does not imply that trading costs are lower on the NASDAQ. A comparison of the results in figure 1 with McInish and Wood (1992) shows that the percentage spread for NYSE securities varies between 1.12% and 1.28%, whereas the percentage spreads for our sample of NASDAQ stocks varies between 1.68% and 1.77%. These values also indicate that the variation in bid-ask spreads is considerably higher for NYSE stocks.

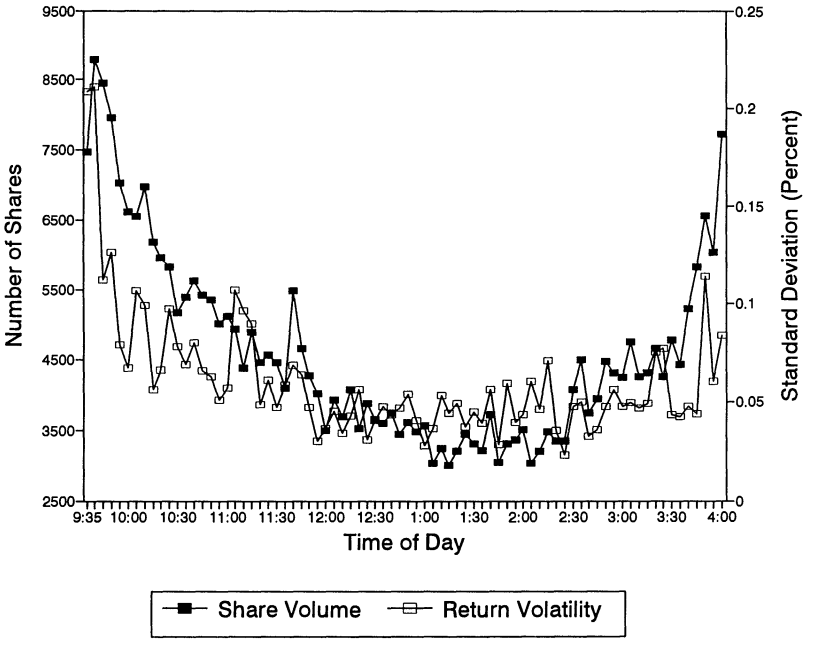


FIG. 2.—The intraday variation in total share volume and return standard deviations. Total share volume is expressed as a daily average per stock, while the return volatility is computed from the midpoint of the inside bid and inside ask prices at the end of each 5-minute interval. The data use all quotes for both the 1991 and 1992 samples.

close cannot be attributed to differences in the intraday pattern of return variability.

Figure 2 also plots the intraday variation in total share volume expressed as a daily average per stock. The figure clearly indicates that share volume is highest at the beginning and the end of the trading day, although the volume during the opening 5 minutes of trading is depressed relative to the following 10 minutes. The strong U-shaped pattern in trading volume for NASDAQ stocks is comparable with the results documented for NYSE securities and cannot explain the intraday differences in bid-ask spreads across markets.[12]

VII. Institutional Explanations for the Intraday Pattern of Spreads for NASDAQ Stocks

A. Price Discovery

One of the main institutional differences between the specialist and the dealer market is the mechanism for price discovery. In a dealer

12. Formal tests, analogous to those reported in table 3, confirm the statistical significance of the increase in volume and volatility near the open and the close.

market, individual market makers sense the willingness of investors to trade by posting bid and ask prices that attract trades based on the competitiveness of the quotes. The search for a sustainable price on the NASDAQ might require a progression of trades for which dealers are willing to commit increasingly larger share volumes. Alternatively, dealers may post wider spreads to protect themselves from losses to informed traders. However, figure 1 indicates that the average inside spread for NASDAQ stocks does not narrow within the first hour of trading.

To explore the potential impact of price discovery on trading activity, figure 3 decomposes the total share volume per 5-minute interval into its two components: the total number of trades, expressed as a daily average per stock, and the average share volume per trade. The figure indicates that the average number of trades follows a U-shaped pattern, with a maximum of slightly over 5.5 trades during the first 5 minutes, declining to a minimum of 1.5 trades around 2:00 P.M., and increasing steadily to over 3.5 trades prior to the close. Thus, the NASDAQ market is characterized by a heavy concentration of trades near the open and close, which is most pronounced during the first few minutes after the open.

In light of the suppressed share volume during the opening 5 minutes, these results imply that the average trade size should be near its intraday minimum over the same period. This conjecture is confirmed in figure 3, as the average trade size of slightly over 1,300 shares during the opening 5 minutes is less than 60% of the intraday average and constitutes the lowest intraday value by a margin of over 500 shares.[13] Examination of the one-minute intervals (not shown) indicates that the average number of trades (per stock) declines rapidly from 1.8 trades at 9:32 A.M. to 0.7 trades at 9:45 A.M. In addition, the average trade size at 9:31 A.M. is slightly over 800 shares, and increases monotonically during the first 5 minutes of trading to a level of slightly over 1,500 shares. In fact, the average trade size during the opening 2 minutes is one-third the average value observed after 9:45 A.M. This evidence implies that price discovery on the NASDAQ appears to be accomplished, not through wide bid-ask spreads, but through a short period of rapid trading when dealers are initially reluctant to commit to large trades.

Additional evidence on the price discovery process is obtained by studying the number of intraday quote revisions. If trades are more informative at the open, the number of quote revisions would be high relative to the other trading periods. Table 3 tests for intraday differences in the number of quote revisions. The table shows that the number of quote revisions is approximately 100% higher during the opening

13. The spike in average trade size at 11:40 A.M. does not reflect a data error in either of the two subsamples.

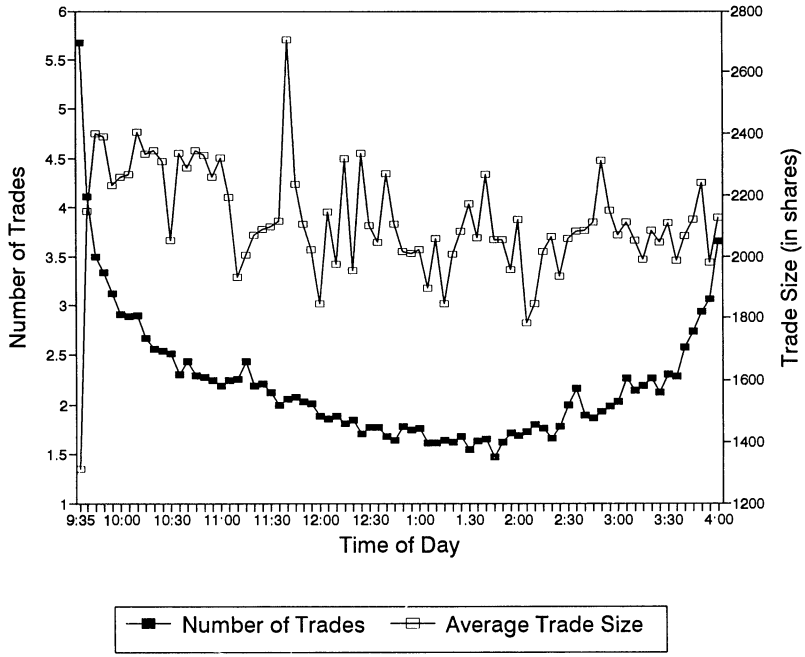


FIG. 3.—The intraday variation in the total number of trades and the average trade size. The total number of trades is expressed as a daily average per stock. Both variables are computed using 5-minute intervals. The data use all quotes for both the 1991 and 1992 samples.

30 minutes than during the rest of the trading day. The number of quote revisions then retreats rapidly during the midday period and increases moderately near the close. This evidence is reinforced by figure 4, which plots the average number of quote revisions per 5-minute interval. The figure illustrates the large number of revisions immediately subsequent to the open and the tendency for quote revisions to become more frequent again near the close.

In interpreting our results relative to those of NYSE stocks, the absence of a decline in bid-ask spreads after the open for NASDAQ stocks may reflect the inability of multiple dealers to exploit the inelastic demand of investors to trade that Brock and Kleidon (1992) use to explain the wider spreads for NYSE stocks. An alternative interpretation is that each market engages in a period of price discovery but that specialists widen their spreads during the period of price uncertainty, while NASDAQ dealers avoid committing to large trades.

B. The Control of Inventory through Intraday Bid and Ask Quotes

Figure 1 illustrates that the decline in the inside spread near the close is not shared by the average dealer spread, implying that the inside spread is effectively moving away from the average quotes of all deal-

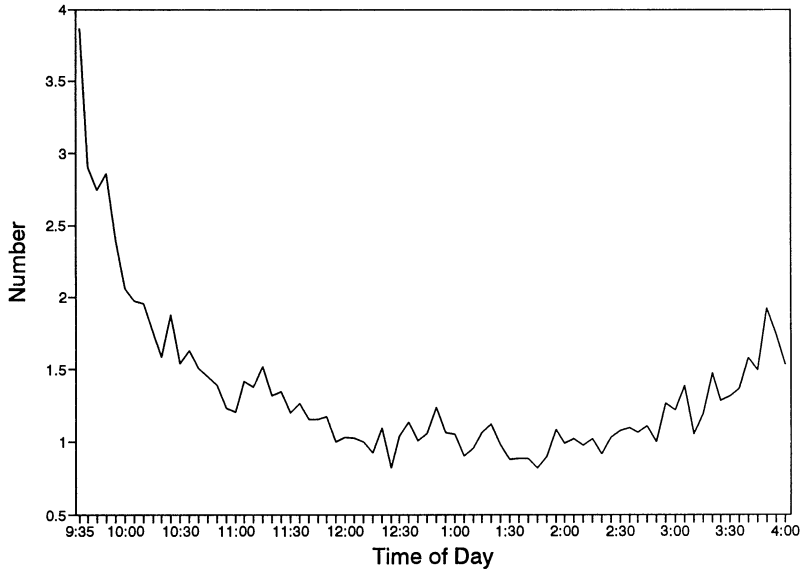


FIG. 4.—The intraday variation in the number of quote revisions. The averages are computed using 5-minute intervals. The data use all quotes for both the 1991 and 1992 samples.

ers. The narrowing of the inside spread near the close may arise from a fraction of dealers raising (lowering) their bid (ask) quotes to control inventory. Under this hypothesis, the percentage of dealers at the inside bid and inside ask should also decline as trading approaches the close. To examine this hypothesis, figure 5 plots the intraday patterns for the percentage of dealers posting inside bid or inside ask quotes at the end of each 5-minute interval. This percentage fluctuates between 41.5% and 42.5% from the open through 12:30 P.M. The percentage then declines, particularly during the final hour of trading, and attains its intraday minimum of slightly over 38.5% at the close. Thus, the time interval when the inside spread narrows coincides with the period when the number of dealers participating at the inside is at its intraday minimum.

Table 3 formally tests whether the reduction in the percentage of dealers at the inside is observed at both the inside bid and the inside ask. The results, which are generally consistent across sample periods, indicate that the percentage of dealers at the inside bid decreases throughout the trading day, with the largest decline emerging during the final 30 minutes. A similar pattern is observed for the percentage of dealers at the inside ask, although the decline during the last 30 minutes is not as dramatic.

The persistent reduction in the inside spread near the close, coupled

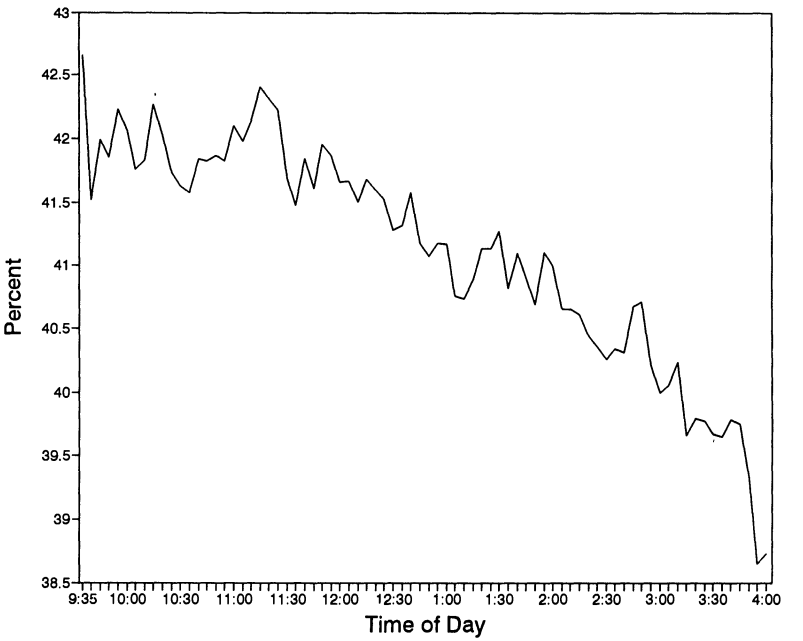


FIG. 5.—The intraday variation in the percentage of dealers that post quotes at either the inside bid or the inside ask. The percentages are computed at the end of each 5-minute interval. The data use all quotes for both the 1991 and 1992 samples.

with the reduction in the percentage of dealers at the inside, is consistent with individual dealers attempting to obtain optimal inventory positions prior to the close by posting more competitive bid or ask quotes to divert order flow from other market makers.[14] The increased number of quote revisions during the final hour of trading, documented in figure 4, also emerges when individual dealers post quotes that reestablish the inside prices.

Unfortunately, our evidence on the use of prices to control inventory is indirect since our data do not permit trades to be assigned to individual dealers.[15] However, attempts by NASDAQ dealers to manage their inventory through prices are indicated by other aspects of our data.

14. While Christie and Schultz (1994) report that a majority of their NASDAQ sample are quoted exclusively in even-eighths, they also report considerable dispersion in the spreads produced by these quotes, permitting dealers the latitude to attract orders through prices.

15. Although the Bridge Quotation System identifies quotes by the originating dealer, all trades are unassigned. In addition, direct trades between market makers and their retail customers are unobservable, preventing us from observing the entire order flow and identifying inventory positions by dealer.

The effective control of inventory implies that market makers would post quotes that appear on only one side of the inside spread. To examine whether individual dealers are often competitive on both sides of the inside spread, we calculate the average percentage of the total trading time that each dealer spends simultaneously at the inside bid and inside ask. We then average these times across dealers for each stock and calculate the mean and median of these averages across stocks. We find that, for the 1991 sample, the average time that dealers spend at both the inside bid *and* the inside ask is 0.7%, while the median is under 0.1%. Even stronger results are obtained for the 1992 sample. Thus, dealer quotes that lie at both the inside bid and inside ask are extremely rare, suggesting that market makers do not post quotes to attract order flow simultaneously on both sides of the inside spread.[16]

One interesting characteristic of spreads that does emerge when dealers simultaneously post quotes at the inside bid and inside ask is that the width of the spread is unusually large. For example, an average inside spread of \$0.69 emerges when dealers elect to post quotes at both the inside bid and inside ask, compared to an average spread of \$0.36 for the full sample in 1991. Thus, the simultaneous posting of bid and ask quotes at the inside may be motivated by the larger than average profits that can be earned from abnormally wide spreads.

Finally, table 4 provides evidence that inventory control can occur over short time intervals by reporting the frequency of quote changes that (1) remove dealers *from* the inside bid or inside ask, (2) move dealers *between* the inside bid and inside ask, (3) move dealers *to* the inside bid or inside ask, or (4) maintain a dealer's quote *away from* the inside bid and inside ask. The table distinguishes between active and inactive market makers, where an active market maker averages at least 2 hours per day at the inside quote.[17] Distinguishing between market makers along this dimension is important in the present context since inactive market makers are unlikely to accumulate unwanted inventory. The use of prices to control inventory implies that dealers move between the inside bid and inside ask when necessary to maintain their desired positions. The results, which are consistent across sample periods, indicate that active dealers move to the inside bid (ask) after previously quoting at the inside ask (bid) approximately 1.5 times per day. In addition, active dealers make separate moves to the

16. Reiss and Werner (1994) find that London Stock Exchange dealers also quote on only one side of the spread at any time. This suggests that London dealers have a similar ability to control inventory and that the similar decline in spreads near the close for London and NASDAQ stocks may arise from the same source.

17. Although our definition of an active market maker is arbitrary, our results are maintained under alternative specifications.

TABLE 4 Frequency of Market Maker Quote Revisions Relative to the Inside Spread

			Distribution of Quote Changes per Market Maker per Day across Categories									
	Number of Dealers		Moves from the Outside to the Inside		Moves from the Inside to the Outside		Moves to the Opposite Side of the Inside Spread		Moves to Remain Outside Prevailing Quote		Total Quote Changes	
Distribution across Stocks	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
A. Statistics for 17 NASDAQ stocks between October 14 and December 6, 1991:												
Mean	17.2	12.5	1.52	.85	1.67	1.90	1.47	.25	.93	2.86	5.59	5.86
Minimum	8	0	.23	.31	.21	.42	.24	.06	.34	.64	1.02	2.01
Maximum	32	26	4.18	2.10	5.16	4.69	3.64	.54	1.78	5.98	13.79	13.00
B. Statistics for 18 NASDAQ stocks between August 11 and September 18, 1992:												
Mean	20.94	11.89	1.17	.55	1.19	1.23	.70	.15	.89	2.18	3.95	3.96
Minimum	11	0	.19	.09	.13	.08	.13	.03	.27	.91	.97	1.16
Maximum	36	30	2.52	1.22	3.01	3.13	2.32	.46	1.69	3.83	8.63	8.22

NOTE.—A market maker is defined as active if the dealer averages 2 hours or more per day at the inside quotes. All quote changes by each market maker are classified into one of four mutually exclusive types of quote changes. A move to the inside includes dealer quote changes to the prevailing inside spread and quote changes that improve the inside. Moves to the opposite side of the inside spread are those where the dealer spent no time away from the inside between quote revisions. The means for each security are computed from the averages of the number of quote changes that fall into each category per day across all market makers. The table describes the cross-sectional distribution across individual stocks.

inside bid or inside ask after quoting away from the inside approximately 1.5 times per day.

Although the total number of quote changes for the active and inactive dealers are similar, they arise from very different sources. The major difference between the active and inactive dealers lies in their willingness to remain at or away from the inside. On average, inactive dealers change their quotes to lie at the inside less than once per day and move between the inside bid and inside ask every 4 days. Even more striking is the frequency with which inactive dealers change quotes to stay away from the inside. Inactive dealers alter their quotes almost three times per day for the purpose of avoiding the inside, whereas active market makers make fewer than one quote change per day to remain outside the prevailing spread. Thus, inactive market makers appear to pursue a strategy of remaining inactive by changing quotes in order to outrun the inside spread.

In summary, table 4 supports the premise that individual NASDAQ market makers attempt to control inventory through prices within the trading day. Individual dealers are rarely observed on *both* sides of the inside bid and inside ask. In addition, active market makers shift between the inside bid and inside ask on average approximately once per day and move either to or away from the inside spread almost three times per day.

VIII. Conclusions

This article documents the intraday patterns of inside bid-ask spreads for two samples of NASDAQ stocks. We find that the average width of the bid-ask spread remains relatively stable during most of the trading day but narrows significantly during the period immediately preceding the close. This pattern contrasts with the results for NYSE stocks reported by Brock and Kleidon (1992) and McInish and Wood (1992), who report that average inside spreads are widest at both the open and the close. We show that the discrepancy between the intraday width of bid-ask spreads across market structures cannot be attributed to either volume or volatility, as these variables display strong U-shaped patterns similar to those reported for NYSE securities. Since information-based models do not imply different intraday patterns for bid-ask spreads across markets, we appeal to the structural differences to reconcile these results.

Stoll and Whaley (1990) suggest that NYSE opening procedures provide the specialist with market power at the beginning of the day. Brock and Kleidon (1992) argue that the combination of the specialists' market power and the inelastic demand of investors to trade permits specialists to widen spreads near the open. Our finding that NASDAQ spreads do not narrow soon after the open provides indirect support for these models.

It is also possible that the difference in intraday spreads across market structures at the open results from different mechanisms for price discovery. We find that for NASDAQ stocks, spreads are relatively stable immediately following the open, although volumes are abnormally heavy and trade sizes are abnormally small. We interpret this pattern as evidence of price discovery, where dealers initially avoid committing to large trades but overcome their reluctance as they become more confident of the equilibrium price.

Our finding that the spreads of NASDAQ stocks do not widen near the close is consistent with the absence of market power among NASDAQ dealers that Brock and Kleidon (1992) use to account for the wider spreads for NYSE stocks near the close. However, their model cannot explain the narrowing of NASDAQ spreads during this period. We provide evidence that the differences in spreads for NYSE and NASDAQ stocks near the close may arise from the different regulatory constraints on inventory control across market structures. While NYSE specialists must both buy and sell to fulfill their obligation to maintain a fair and orderly market, we show that NASDAQ dealers almost always post quotes that place them on only one side of the inside spread. Individual dealers who wish to avoid the risk of maintaining a position overnight may post quotes that improve the inside spread near the close to divert orders from other dealers. Consistent with this conjecture, we find that the narrowing of the inside spread near the close arises from a minority of dealers moving within the spread. Thus, the conclusion by Hasbrouck and Sofianos (1993) and Madhavan and Smidt (1993) that inventory management is unimportant for NYSE specialists may have been influenced by the institutional features of the specialist system. Our evidence in support of inventory control among NASDAQ market makers suggests that this practice is important but difficult to implement in other markets.

Our results suggest that the intraday patterns of bid-ask spreads are materially affected by the structural differences between dealer markets and the organized exchanges. These results imply that tests for the importance of information asymmetries in determining intraday spreads, as modeled by Admati and Pfleiderer (1988), Foster and Viswanathan (1990), and Madhavan (1992), must first consider the impact of institutional factors.

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