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## Why Did NASDAQ Market Makers Stop Avoiding Odd-Eighth Quotes?

WILLIAM G. CHRISTIE, JEFFREY H. HARRIS, and  
PAUL H. SCHULTZ\*

### ABSTRACT

On May 26 and 27, 1994 several national newspapers reported the findings of Christie and Schultz (1994) who cannot reject the hypothesis that market makers of active NASDAQ stocks implicitly colluded to maintain spreads of at least \$0.25 by avoiding odd-eighth quotes. On May 27, dealers in Amgen, Cisco Systems, and Microsoft sharply increased their use of odd-eighth quotes, and mean inside and effective spreads fell nearly 50 percent. This pattern was repeated for Apple Computer the following trading day. Using individual dealer quotes for Apple and Microsoft, we find that virtually all dealers moved in unison to adopt odd-eighth quotes.

THIS ARTICLE DOCUMENTS A sudden and dramatic narrowing of the inside spreads for Amgen Inc., Apple Computer Inc., Cisco Systems, Intel Corp., and Microsoft Corp. As Table I indicates, each of these stocks is among the 10 most actively traded firms listed on the National Association of Securities Dealers Automated Quotation System (NASDAQ) in 1993. These stocks are traded by at least 40 market makers and are among the largest market capitalization stocks listed on NASDAQ. Despite their high volume and visibility, each of these issues was quoted with spreads of at least \$0.25 throughout 1993 and the first five months of 1994. However, the inside spreads for Amgen, Cisco, and Microsoft fell by nearly 50 percent beginning on May 27 and have averaged between \$0.151 and \$0.175 through July 1994. The inside spread for Apple Computer fell by almost 50 percent on the following trading day, while Intel spreads declined by a smaller amount on June 10. This shift in the width of the inside spreads is remarkable both in its rapidity and its magnitude.<sup>1</sup>

\* Christie is from the Owen Graduate School of Management, Vanderbilt University, while Harris and Schultz are from the Max Fisher College of Business, The Ohio State University. The article has benefitted from the comments and suggestions of Clifford Ball, Stephen Buser, David Mayers, Kelly McNamara, Timothy Opler, Hans Stoll, René Stulz, Ralph Walkling, seminar participants at The Ohio State University and Vanderbilt University, and an associate editor of the *Journal of Finance*. 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. Schultz acknowledges the financial support from the Dice Center for Financial Research at The Ohio State University. All errors are the joint property of the authors.

<sup>1</sup> All of our empirical results use data through July 29, 1994. However, an examination of data obtained from the Bridge Quotation System reveals that quoted and effective spreads during August 1994 are very similar to those observed during June and July 1994.

**Table I**  
**The 10 Most Active NASDAQ Market Issues in 1993 Ranked by  
 Total Share Volume**

The stocks whose inside spread is never below \$0.25 per share throughout April 1994 are identified by an \*\*. These data are obtained from the 1994 *NASDAQ Fact Book and Company Directory*.

| Company Name                               | Ticker Symbol | Share Volume<br>(Thousands) |
|--------------------------------------------|---------------|-----------------------------|
| Intel Corporation**                        | INTC          | 1,049,801                   |
| Novell Inc.                                | NOVL          | 835,712                     |
| Tele-Communications, Inc.                  | TCOMA         | 702,218                     |
| MCI Communications<br>Corporation          | MCIC          | 549,109                     |
| Cisco Systems, Inc.**                      | CSCO          | 527,391                     |
| Spectrum Information<br>Technologies, Inc. | SPCL          | 523,643                     |
| Microsoft Corporation**                    | MSFT          | 507,276                     |
| Apple Computer, Inc.**                     | AAPL          | 504,138                     |
| Amgen, Inc.**                              | AMGN          | 500,015                     |
| Oracle Systems Corporation                 | ORCL          | 449,654                     |

The narrowing of quoted spreads has led to a significant and real reduction in the costs that investors pay for market making services. We find that effective spreads, which measure investors' actual transactions costs by incorporating the location of the trade price relative to the bid-ask midpoint, decrease by more than 40 percent when quoted spreads fall. Although the effective spreads decline for all trade sizes, they fall most sharply for small trades.

The decline in trading costs at the end of May 1994 is not explained by contemporaneous changes in the stocks' volatilities, prices, or trading volumes. Instead, our evidence suggests that spreads narrowed because an implicit agreement among market makers to maintain spreads of at least \$0.25 was abandoned. Specifically, on May 26 and May 27, *The Los Angeles Times*, *The Wall Street Journal*, and other newspapers reported the findings of Christie and Schultz (1994) that implicit agreements among market makers is the most likely explanation for the absence of odd-eighth quotes for active NASDAQ stocks.<sup>2</sup> Coincidentally, dealers began to routinely quote Amgen, Cisco, and Microsoft in odd eighths on May 27, and spreads collapsed as a result.

This article proceeds as follows. Section I describes the sources and characteristics of the trade and quote data for our five stocks. Section II demonstrates that the average daily inside spread for these securities falls below \$0.25 at the end of May for four of the stocks and early in June for the fifth, after fluctuating between \$0.25 and \$0.45 throughout the preceding 17

<sup>2</sup> These results were released to the press on Tuesday May 24.

months. We also show that these reductions in posted quotes were matched by a decline in the effective spreads. Section III tests whether spreads narrowed due to a decline in the costs of making markets, or because implicit agreements among NASDAQ dealers to quote these stocks exclusively in even eighths were abandoned. Section IV provides a summary of our findings.

## **I. Data Description**

The trade and quote data are obtained from two sources. Data for the period from the beginning of January, 1993 through July, 1994 are obtained from the trade and quote (TAQ) data compiled by the New York Stock Exchange (NYSE). Inside quotes are time-stamped to the nearest second and are updated whenever the inside bid and/or ask changes. Trades are also time-stamped to the nearest second. A series of filters are applied to the trades and quotes to eliminate data errors. We remove all inside spreads that exceed \$10. We also discard quotes where the bid or ask lies below \$10 or above \$200 and thereby remove data with either a missing or an additional digit. Quotes that originate on regional exchanges or from other non-NASDAQ sources are removed. We eliminate all trades that are coded as errors by the NYSE. Since our estimates of effective spreads require the precise time of a trade's execution, we eliminate trades that are: (1) labeled as a bunched order reported more than 90 seconds late, (2) reported late (but in sequence), (3) reported after the close, and (4) reported out of sequence. However, we retain out-of-sequence trades when calculating the proportion of trades that occur on different price fractions. Finally, trades that occur outside the quoted spread may be the result of data errors. In calculating effective spreads, we eliminate all trades that were more than \$0.25 outside of the inside spread during the period prior to odd-eighth usage but retain all trades after market makers started to routinely quote odd eighths.<sup>3</sup> Thus the effective spread estimates after odd eighths are used are biased upward relative to the prior period, and the change in effective spreads is portrayed conservatively.

The second data source, which provides individual dealer quotes, is the Bridge Quotation System. We downloaded screens of real-time quotes from May 23, 1994 through June 24, 1994 for Apple Computer, May 31 through June 28 for Intel, and May 25 through June 29 for Microsoft.<sup>4</sup> The quote data are time-stamped to the minute and consist of each bid and ask and the identity of the originating market maker for all quotes posted throughout the day. Prevailing inside quotes are also provided. Thus, the Bridge data supple-

<sup>3</sup> In addition, 324 Microsoft trades that were reported at 10:34:33 on April 4, 1994 (after the market closed and reopened) are discarded. The results are qualitatively unaffected by excluding these trades and the trades that were more than \$0.25 outside the spread.

<sup>4</sup> These data are available for Apple, Intel, and Microsoft as they had been previously downloaded. Since this data is retained for only one week on the Bridge system, they are unavailable for the other stocks.

ments the historical evidence on the width of inside bid-ask spreads from the TAQ data by permitting us to identify whether changes in the inside spread can be attributed to changes in the quotes of a few dealers, or whether market makers moved together to change inside spreads.

## **II. Quoted and Effective Spreads**

This section establishes that both the quoted and the effective spreads narrow dramatically for all five issues within the span of a few trading days in mid-1994. The quoted spread is defined as the difference between the inside ask and the inside bid. The effective spread is computed as twice the absolute value of the difference between the trade price and the average of the inside bid and ask.

### *A. Quoted Spreads*

Figure 1 provides the average inside spread for each stock on every trading day between January 2, 1993 and July 29, 1994.<sup>5</sup> To compute the average daily inside spread, we multiply each inside spread by the proportion of the trading day that the spread was in effect. Figure 1 shows three distinct patterns. First, the interday time-weighted spreads display considerable variation between \$0.25 and \$0.45 prior to the end of May, 1994. Second, despite their status as NASDAQ's largest and most active stocks, the average time-weighted spread never breaks through the lower bound of \$0.25 per share for any of the 5 stocks for the 17 months beginning in January 1993. Indeed, \$0.25 appears to serve as a barrier for the spread for this entire time period.

The most significant feature of Figure 1 is the narrowing of inside spreads of Amgen, Cisco, and Microsoft beginning on May 27, 1994. The average inside spread for each stock falls from approximately \$0.30 per share on May 26 to approximately \$0.15 per share on May 27. For Apple Computer, the mean inside spread falls through the \$0.25 barrier on May 31 to approximately \$0.21. The average inside spread falls further to \$0.15 on the following trading day. The figure shows that there is no tendency for the inside spread to return to its previous levels, implying that the change in the width of the inside spread for each of these stocks is permanent.

The last stock, Intel, does not display a narrowing of spreads to under \$0.25 until June 10. While the spread does reach its lowest levels in 18 months at this time, the shift is not as abrupt as observed for the other four stocks.

### *B. Effective Spreads*

Although Figure 1 documents a narrowing in the quoted spread for each stock, the quoted spread may not reflect the trading costs borne by investors,

<sup>5</sup> We removed July 15, 1994 from Figure 1 as NASDAQ experienced difficulties when installing new operating software, resulting in numerous locked and crossed quotes.

since trades can be executed between the inside bid and ask. Thus, we also consider a measure of trading costs that incorporates the location of the trade price relative to the "best price," defined as the mid-point of the bid-ask quotes. The effective spread (ES) is calculated as follows for every transaction:

$$ES = 2 \left| Trade\ Price - \left( \frac{Ask + Bid}{2} \right) \right|. \quad (1)$$

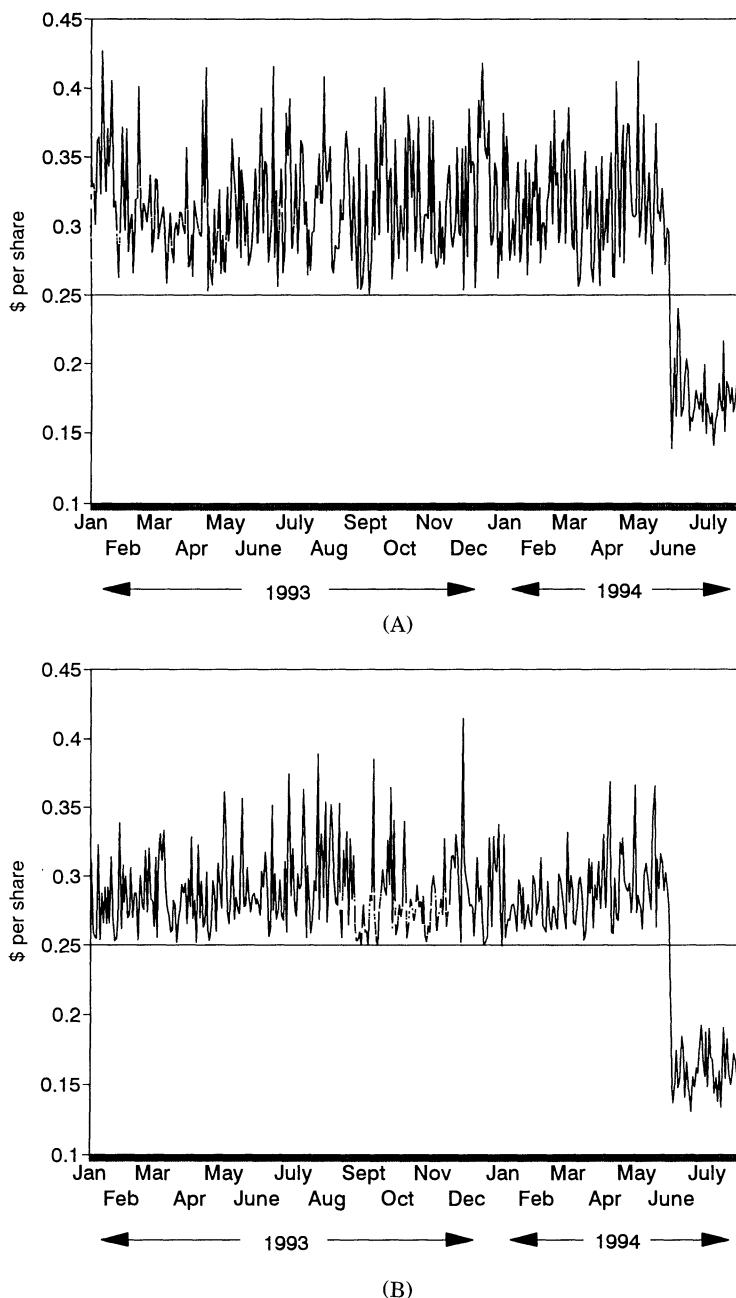
The bid and ask quotes used in equation (1) represent the prevailing inside quote at the time of the transaction. If the time-stamp for the trade is identical to that of the quote, the previous inside spread is used. If the contemporaneous quote is locked (bid equals ask) or crossed (bid is greater than ask), the effective spread for a trade is calculated with the previous valid quote.

Table II shows that the average effective spreads for Amgen, Apple, Cisco, and Microsoft were between 17 cents (for trades between 1,001 and 5,000 shares) and 30 cents per share (for 100 share trades) for the 17 months prior to the end of May and fell to between 10 cents and 16 cents per share for the period beginning on May 27, 1994.<sup>6</sup> The collapse of the effective spreads and the narrowing of the quoted spreads documented in Figure 1 occur simultaneously. Therefore, the decline in the actual trading costs for these NASDAQ stocks appears to correspond closely to the decline in the width of the inside spreads. The results for Intel show that although the effective spreads, like the quoted spreads, do not decline as abruptly as for the other stocks, they do fall by several cents per share for all trade size categories.

An interesting characteristic of the effective spreads that is consistent across stocks is that effective spreads decline monotonically with trade size over the range from 100 through 5,000 shares. Prior to the collapse of the quoted spreads, the effective spreads for 100-share trades were \$0.095 to \$0.12 greater than the effective spreads for trades of 1,001 to 5,000 shares. Effective spreads increase slightly for trades of 5,001 to 10,000 shares and increase further for trades that exceed 10,000 shares. However, investors who trade more than 10,000 shares still receive a superior price to those who trade only 100 shares. This contrasts sharply with the Petersen and Fialkowski (1994) finding that mean effective spreads are smaller for 100-share trades than for any larger size trade for NYSE listed stocks between November 1990 and January 1991.

One aspect of the trade price data that has a direct bearing on our examination of trading costs is the change to reporting trade prices in increments that are finer than one-eighth. While quotes are restricted to increments of one-eighth if the bid price exceeds \$10, the National Association of Securities Dealers (NASD) permits trades in increments of sixty-

<sup>6</sup> It is also notable that the decline in effective spreads corresponds almost perfectly to the reductions in a comparable measure of trading costs noted by Christie and Huang (1994) for stocks that move from NASDAQ to the organized exchanges.



**Figure 1. The time series of daily average inside spreads.** For each stock, we obtain all the inside spreads during regular trading hours between January 1, 1993 and July 29, 1994, excluding July 15, 1994 when NASDAQ experienced difficulties installing new operating software that resulted in numerous locked and crossed quotes. The daily average inside spread is calculated by multiplying each inside spread by the proportion of the trading day that the spread is in effect. Panel A: Amgen, Inc.; Panel B: Apple Computer, Inc.; Panel C: Cisco Systems, Inc.; Panel D: Intel Corporation; and Panel E: Microsoft Corporation.

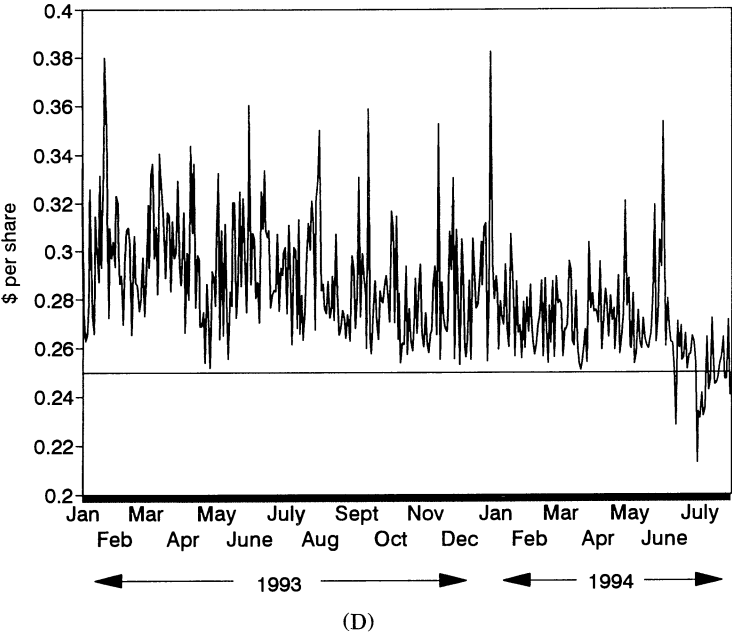
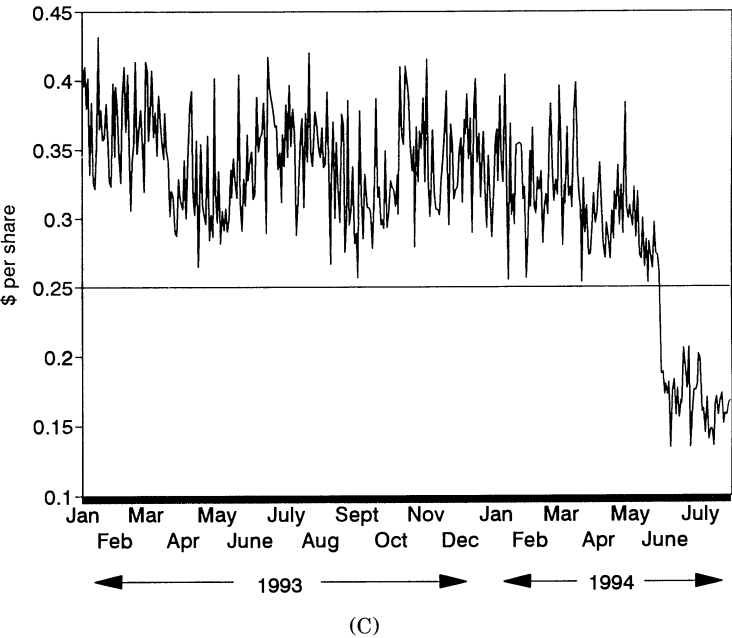
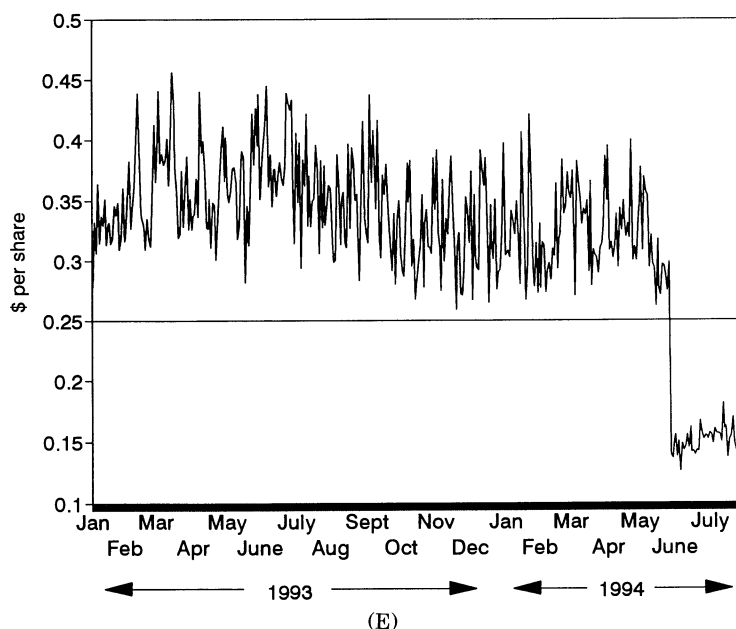


Figure 1.—Continued.

**Figure 1.**—*Continued.*

fourths for all stocks. Prior to April 5, 1994, trade prices that used increments finer than one-eighth were rounded up to the nearest eighth for reporting. However, effective April 5, NASDAQ began reporting the actual trade price.

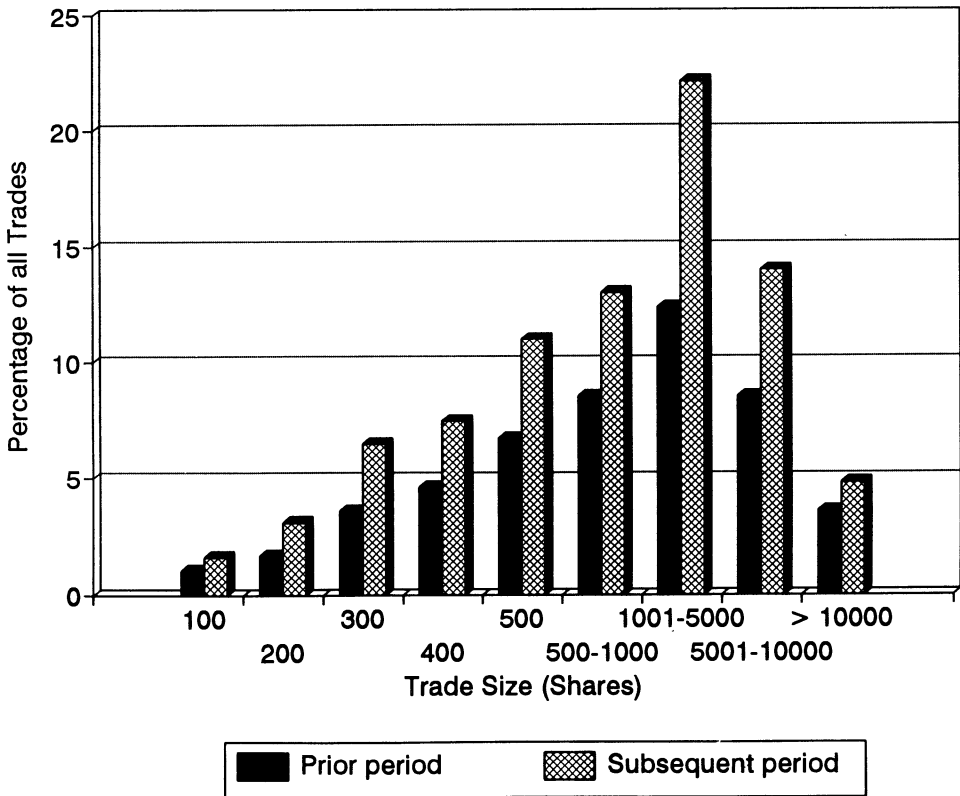
To examine the importance of trades on price increments narrower than one-eighth, Figure 2 plots the percentage of trades (averaged across all five stocks) that use sixteenth, thirty-second, or sixty-fourth price fractions for different trade sizes. The figure uses data subsequent to April 5 and distinguishes between the period before and after the inside spreads decline below \$0.25 for each stock. Two important features are revealed in Figure 2. First, executions occur at these finer price increments in less than 2 percent of all trades of 100 or 200 shares. Interestingly, this small fraction is also a feature of trade sizes that exceed 10,000 shares. The greatest use of fine price increments occurs in trades of intermediate size, most noticeably trades of 1,001 to 5,000 shares. Within this range, we find that approximately 12.5 percent of trades are executed at the finer price increments.

The second interesting result is that the frequency of finer price increments increases significantly for intermediate size trades after spreads fall below \$0.25. For example, the percentage of price fractions under one-eighth for trades of 1,001 to 5,000 shares jumps to approximately 22 percent in June and July 1994. However, such price improvement does not materialize in the smallest and largest trades.

**Table II**  
**A Comparison of Average Effective Spreads Across Trade Sizes**

For each stock, the average effective spread is calculated as the mean, across all transactions of a given size, of the absolute value of twice the difference between the trade price and the average of the inside bid and ask. The results are presented in cents per share for roundtrip transactions. *T*-statistics (not shown) reveal that the paired estimates of effective spreads for each trade size differ at the 1 percent significance level for each of the 5 stocks.

| Trade Size<br>(shares) | Amgen              |       |                     |       | Apple                          |       |                     |       | Cisco              |       |                     |  | Intel             |  |                     |  | Microsoft          |  |                     |  |
|------------------------|--------------------|-------|---------------------|-------|--------------------------------|-------|---------------------|-------|--------------------|-------|---------------------|--|-------------------|--|---------------------|--|--------------------|--|---------------------|--|
|                        | 1/2/93-<br>5/26/94 |       | 5/27/94-<br>7/29/94 |       | 1/2/93-<br>5/31/94-<br>7/29/94 |       | 5/27/94-<br>7/29/94 |       | 1/2/93-<br>5/26/94 |       | 5/27/94-<br>7/29/94 |  | 1/2/93-<br>6/9/94 |  | 6/10/94-<br>7/29/94 |  | 1/2/93-<br>5/26/94 |  | 5/27/94-<br>7/29/94 |  |
|                        |                    |       |                     |       |                                |       |                     |       |                    |       |                     |  |                   |  |                     |  |                    |  |                     |  |
| 100                    | 28.94              | 16.21 | 27.09               | 15.01 | 29.53                          | 15.73 | 27.04               | 23.51 | 30.76              | 14.44 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 200                    | 28.11              | 15.69 | 26.43               | 14.72 | 28.00                          | 15.37 | 26.16               | 22.81 | 27.38              | 14.05 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 300                    | 27.05              | 14.63 | 25.19               | 13.81 | 26.20                          | 14.93 | 24.60               | 20.80 | 24.96              | 13.05 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 400                    | 25.35              | 14.18 | 24.14               | 13.87 | 25.73                          | 14.36 | 23.75               | 19.92 | 24.52              | 12.85 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 500                    | 22.81              | 13.18 | 21.60               | 12.33 | 22.44                          | 13.36 | 21.24               | 17.98 | 21.48              | 12.27 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 501-1000               | 20.37              | 11.52 | 19.78               | 11.22 | 21.52                          | 12.50 | 20.56               | 17.10 | 20.91              | 11.25 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 1001-5000              | 17.00              | 10.82 | 16.17               | 10.34 | 18.59                          | 10.91 | 17.57               | 15.31 | 18.67              | 10.33 |                     |  |                   |  |                     |  |                    |  |                     |  |
| 5001-10000             | 21.73              | 13.61 | 20.28               | 12.31 | 22.42                          | 12.98 | 22.05               | 17.81 | 24.71              | 12.50 |                     |  |                   |  |                     |  |                    |  |                     |  |
| > 10000                | 23.10              | 13.90 | 22.08               | 13.92 | 22.96                          | 14.81 | 23.75               | 21.18 | 25.03              | 13.70 |                     |  |                   |  |                     |  |                    |  |                     |  |



**Figure 2. The frequency of price increments that are finer than one-eighth.** For each stock, we calculate the percentage of all trades whose price fraction lies on an odd sixteenth, thirty-second, or sixty-fourth. These values are then averaged across stocks. The prior period corresponds to the interval between January 2, 1993 and the last date prior to the inside spread falling to under \$0.25. The subsequent period corresponds to the remaining period through July 29, 1994.

In summary, this section documents a large reduction in the trading costs for four of the five actively traded NASDAQ stocks that we examine. In the remainder of the article, we explore whether the change in the costs of trading results from the collapse of implicit agreements to maintain spreads of at least 25 cents or from a reduction in the costs of making markets.

### III. What Caused Spreads to Narrow?

#### A. Did NASDAQ Market Makers Abandon an Implicit Pricing Agreement?

##### A.1. The Adoption of Odd-Eighth Quotes

An examination of the financial press surrounding the period of the sharp declines in trading costs reveals public and private criticism of the width of

spreads for NASDAQ stocks. The May 30 edition of *Securities Week*, an industry publication, reported that

*Richard Ketchum, NASD CEO, COO and president, along with William Broka, senior vp of trading and market Services, and John Wall, executive vp of marketing and market operations, told a group representing more than 100 major OTC dealers during a meeting at Bear Stearns' headquarters in New York last Tuesday (May 24) to narrow the differences between their bids and offers in order to be competitive with other exchanges and in order to avoid regulation by the NASD and the SEC.*

Thus, the regulatory body overseeing NASDAQ market makers reportedly exerted pressure on dealers to narrow their spreads or face regulations that would force the narrowing of spreads.

On Thursday May 26, the *Los Angeles Times* reported the results of Christie and Schultz (1994), who conclude that implicit agreements among NASDAQ dealers to maintain spreads of at least \$0.25 is the most likely explanation for the absence of odd-eighth quotes for active NASDAQ stocks. The report was also carried in the *Milwaukee Journal*, *Detroit News*, and several other papers. On the following day, similar stories were carried in the *Boston Globe*, *Atlanta Constitution*, and *The Wall Street Journal*. Coincidentally, the spreads for Amgen, Cisco, and Microsoft collapsed on that day. The breakdown in spreads appeared for Apple on the next trading day and for Intel about one week later. Thus, the public disclosure of the practice of quoting a majority of the largest NASDAQ stocks exclusively in even eighths, along with the possible private pressure placed on dealers to improve their quotes, may have persuaded market makers to dismantle an implicit agreement to avoid odd-eighth quotes.

To examine whether the reduction in inside spreads could be attributed to a change in the way these stocks are quoted, Table III reports the daily average of the percentage of inside bid and ask quotes on odd eighths. During early May 1994, the average percentage of odd-eighth inside quotes is 3 percent or less for each of these five stocks. Odd-eighth quotes for these stocks are also exceedingly rare throughout 1993 and the first four months of 1994. This historical precedent is shattered on May 27, as the percentage of odd-eighth inside quotes increases to 37.5 percent for Amgen, 38.2 percent for Cisco, and 39 percent for Microsoft. On the following trading day, the proportion of odd-eighth inside quotes increases to 29.8 percent for Apple. For the remainder of June, the inside spread for each of these four stocks includes an odd eighth at least 40 percent of the time. Interestingly, the simultaneous emergence of odd-eighth quotes at the inside bid or ask on May 27 or May 31 is not shared by Intel. The proportion of odd-eighth inside quotes for Intel does increase in early June but only to 15 to 20 percent of the quotes rather than 40 to 50 percent.

If odd eighths are not used to quote a stock, spreads of \$0.125 cannot arise. Figure 3 shows the percentage of time that spreads are \$0.125 on each day.

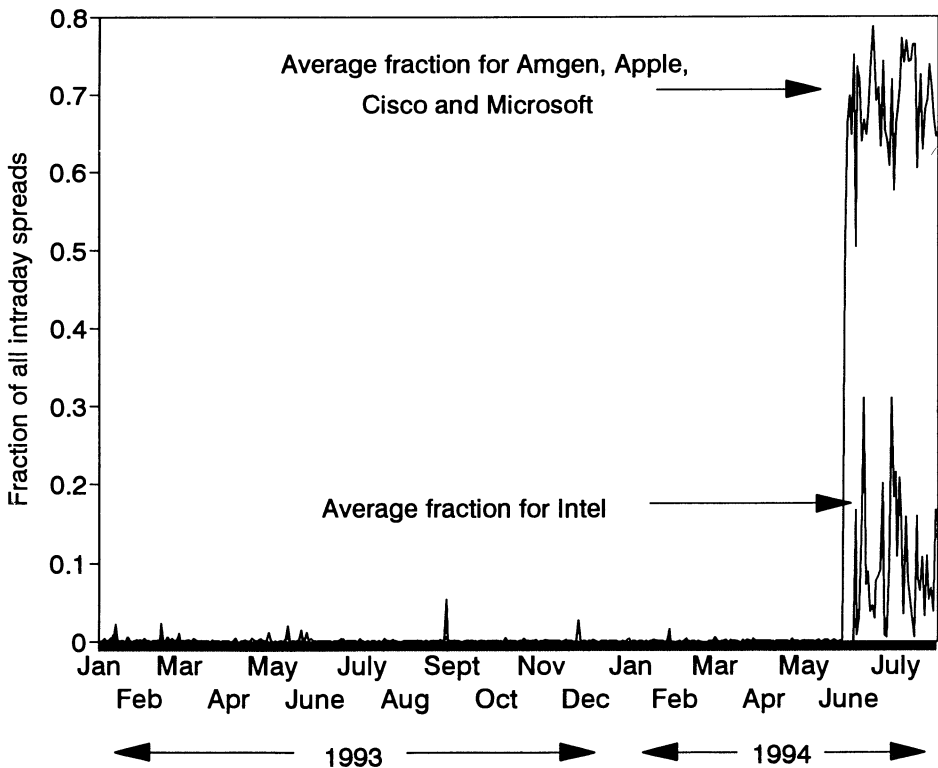
**Table III**  
**The Time Series of the Average Percentage of Odd-Eighth Quotes**

The percentages reflect an average of the fraction of odd-eighth quotes at the inside bid and at the inside ask using all intraday quote revisions. The weekly averages are, in each case, representative of the individual daily averages.

| Date<br>(1994) | Amgen<br>(%) | Apple<br>(%) | Cisco<br>(%) | Intel<br>(%) | Microsoft<br>(%) |
|----------------|--------------|--------------|--------------|--------------|------------------|
| 5/2-5/6        | 2.0          | 3.0          | 1.2          | 0.5          | 1.0              |
| 5/9-5/13       | 2.2          | 2.7          | 1.1          | 1.9          | 0.0              |
| 5/16-5/20      | 1.2          | 2.6          | 0.7          | 2.8          | 0.2              |
| 5/23           | 0.0          | 0.0          | 0.0          | 2.0          | 1.6              |
| 5/24           | 2.3          | 0.0          | 0.0          | 2.0          | 0.0              |
| 5/25           | 0.0          | 0.0          | 0.0          | 0.0          | 6.5              |
| 5/26           | 2.8          | 0.0          | 1.3          | 0.0          | 3.3              |
| 5/27           | 37.5         | 6.6          | 38.2         | 0.0          | 39.0             |
| 5/31           | 47.9         | 29.8         | 44.8         | 1.7          | 44.4             |
| 6/1            | 56.5         | 46.5         | 46.6         | 3.6          | 46.9             |
| 6/2            | 51.0         | 47.0         | 47.7         | 0.0          | 47.8             |
| 6/3            | 57.4         | 44.1         | 47.9         | 0.0          | 47.8             |
| 6/6-6/10       | 48.1         | 49.7         | 48.2         | 16.8         | 50.4             |
| 6/13-6/17      | 48.1         | 51.0         | 49.3         | 13.6         | 50.9             |
| 6/20-6/24      | 49.2         | 47.1         | 48.4         | 18.9         | 48.7             |
| 6/27-6/30      | 50.0         | 50.5         | 50.0         | 18.9         | 49.9             |

The figure displays results averaged across Amgen, Apple, Cisco Systems, and Microsoft as one series and depicts the results separately for Intel. For the stocks that shifted from almost no odd-eighth quotes to almost half of the inside quotes on odd eighths, the average percentage of time that inside spreads are \$0.125 rises from almost zero to approximately 70 percent. For Intel, which had a smaller proportion of inside quotes on odd eighths in June and July, the average daily proportion of time that spreads are \$0.125 rises from almost zero to about 10 percent.

The results in Table III and Figure 3 suggest that the change in the inside spread for these stocks may reflect the breakdown of implicit agreements among market makers to post quotes exclusively on even eighths for these issues. This inference is strengthened by the finding that almost all market makers adopted odd eighths on the same day. Table IV reports the number of dealers who post no odd-eighth quotes, the number of dealers whose odd-eighth quotes exceed 40 percent of the total quotes posted by that dealer, the average fraction of odd-eighth quotes across dealers, and the proportion of time that the inside spread was one-eighth for Apple, Intel, and Microsoft. The results for Apple and Microsoft indicate that the switch to quoting odd eighths occurs almost simultaneously for all dealers. For Apple Computer, all 59 market makers quote the issue on May 26 without using odd eighths. This



**Figure 3. The time series of the fraction of inside spreads that are \$0.125.** For each stock, we obtain all the inside spreads during regular trading hours between January 1, 1993 and July 29, 1994, excluding July 15, 1994 when NASDAQ experienced difficulties installing new operating software that resulted in numerous locked and crossed quotes. The daily fractions are the proportion of time that one-eighth spreads are in effect during the regular trading hours. The figure depicts the average daily fractions for Amgen, Apple, Cisco, and Microsoft as one series, while Intel is shown separately.

number falls to 46 on May 27, 18 on May 31, and 0 on June 1. Conversely, no dealers post 40 percent or more of their quotes on odd eighths until May 31, when 2 dealers post odd-eighth quotes regularly. The following day, 36 dealers post at least 40 percent of their quotes on odd eighths.

The impact of using odd-eighth quotes on the width of inside spreads is revealed by comparing the proportion of time that Apple's inside spread was \$0.125 (last column of Table IV) with the number of dealers using odd eighths in at least 40 percent of their quotes. Before May 31, no dealers routinely used odd-eighth quotes and spreads of \$0.125 were almost never observed. When all dealers switched to the regular use of all price fractions, inside spreads of \$0.125 appeared at least 65 percent of the time.

The transition to odd eighths among market makers for Microsoft (Panel B of Table IV) is also swift. On May 26, 41 of the 45 market makers did not post

Table IV

**The Use of Odd-Eighth Quotes by Individual Dealers**

The number of dealers is the total that post at least one quote during a given trading day. To compute the daily fraction of odd-eighth quotes, we first estimate the percentage of individual dealer quotes that contain an odd eighth. We then average these percentages across dealers. The fraction of one-eighth spreads is the proportion of the day that the inside spread is one-eighth. All weekly figures are averages across days.

| Date<br>(1994)                 | No. of<br>Dealers | No. of Dealers<br>Posting No Odd-<br>Eighth Quotes | No. of Dealers Who<br>Enter Over 40% of Their<br>Quotes on Odd Eighths | Fraction of<br>Odd-Eighth<br>Quotes<br>(%) | Fraction of<br>One-Eighth<br>Spreads<br>(%) |
|--------------------------------|-------------------|----------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------|---------------------------------------------|
| Panel A: Apple Computer        |                   |                                                    |                                                                        |                                            |                                             |
| 5/23                           | 58                | 54                                                 | 0                                                                      | 1.1                                        | 0.0                                         |
| 5/24                           | 59                | 57                                                 | 0                                                                      | 0.5                                        | 0.0                                         |
| 5/25                           | 59                | 57                                                 | 0                                                                      | 0.4                                        | 0.0                                         |
| 5/26                           | 59                | 59                                                 | 0                                                                      | 0.0                                        | 0.0                                         |
| 5/27                           | 59                | 46                                                 | 0                                                                      | 3.2                                        | 1.2                                         |
| 5/31                           | 59                | 18                                                 | 2                                                                      | 17.0                                       | 35.7                                        |
| 6/1                            | 58                | 0                                                  | 36                                                                     | 44.5                                       | 81.4                                        |
| 6/2                            | 58                | 0                                                  | 47                                                                     | 47.7                                       | 90.6                                        |
| 6/3                            | 58                | 0                                                  | 44                                                                     | 47.5                                       | 78.4                                        |
| 6/6-6/10                       | 58                | 1.4                                                | 46.4                                                                   | 48.1                                       | 65.7                                        |
| 6/13-6/17                      | 57.8              | 0.4                                                | 47.6                                                                   | 49.3                                       | 82.8                                        |
| 6/20-6/24                      | 58                | 2.4                                                | 46.4                                                                   | 47.9                                       | 71.5                                        |
| Panel B: Microsoft Corporation |                   |                                                    |                                                                        |                                            |                                             |
| 5/25                           | 46                | 38                                                 | 0                                                                      | 1.9                                        | 0.0                                         |
| 5/26                           | 45                | 41                                                 | 0                                                                      | 1.3                                        | 0.1                                         |
| 5/27                           | 45                | 1                                                  | 42                                                                     | 49.1                                       | 88.8                                        |
| 5/31                           | 44                | 0                                                  | 43                                                                     | 49.7                                       | 91.0                                        |
| 6/1                            | 45                | 0                                                  | 44                                                                     | 49.7                                       | 79.9                                        |
| 6/2                            | 44                | 0                                                  | 39                                                                     | 48.9                                       | 74.8                                        |
| 6/3                            | 45                | 0                                                  | 41                                                                     | 50.2                                       | 89.8                                        |
| 6/6-6/10                       | 44.2              | 0.2                                                | 39.2                                                                   | 48.6                                       | 85.5                                        |
| 6/13-6/17                      | 44.4              | 2.8                                                | 35.6                                                                   | 48.4                                       | 79.7                                        |
| 6/20-6/24                      | 44.2              | 0                                                  | 39.6                                                                   | 50.1                                       | 80.3                                        |
| Panel C: Intel Corporation     |                   |                                                    |                                                                        |                                            |                                             |
| 5/31                           | 62                | 59                                                 | 0                                                                      | 0.8                                        | 0.0                                         |
| 6/1                            | 62                | 52                                                 | 0                                                                      | 1.3                                        | 0.0                                         |
| 6/2                            | 61                | 55                                                 | 0                                                                      | 1.0                                        | 0.0                                         |
| 6/3                            | 61                | 55                                                 | 0                                                                      | 0.9                                        | 0.0                                         |
| 6/6                            | 61                | 52                                                 | 1                                                                      | 3.1                                        | 16.7                                        |
| 6/7                            | 61                | 55                                                 | 0                                                                      | 1.7                                        | 0.8                                         |
| 6/8                            | 61                | 44                                                 | 0                                                                      | 2.9                                        | 2.9                                         |
| 6/9                            | 61                | 47                                                 | 1                                                                      | 2.6                                        | 13.1                                        |
| 6/10                           | 61                | 55                                                 | 1                                                                      | 2.2                                        | 31.1                                        |
| 6/13                           | 61                | 53                                                 | 1                                                                      | 2.7                                        | 7.3                                         |
| 6/14                           | 61                | 53                                                 | 1                                                                      | 2.2                                        | 9.0                                         |
| 6/15                           | 61                | 54                                                 | 0                                                                      | 1.7                                        | 3.7                                         |
| 6/16                           | 61                | 54                                                 | 1                                                                      | 2.5                                        | 4.6                                         |
| 6/17                           | 62                | 59                                                 | 0                                                                      | 0.6                                        | 2.8                                         |
| 6/20-6/24                      | 61.8              | 52.4                                               | 0.4                                                                    | 2.0                                        | 9.2                                         |

odd-eighth quotes, and none of the remaining four used odd eighths in 40 percent or more of their quotes. However, this pattern is exactly reversed the following trading day, with only one firm posting no odd-eighth quotes and 42 of the remaining 44 firms using odd eighths in at least 40 percent of their quotes. Inside spreads of \$0.125 were almost never observed prior to May 27 but were typically in effect more than 80 percent of the time from that date on.

The simultaneous change to the use of odd-eighth quotes by the individual market makers for Apple and Microsoft suggests a degree of coordination prior to the shift that is uncharacteristic of competitive markets. Although individual dealer quotes are unavailable for Amgen and Cisco, they display similar reductions in inside and quoted spreads and increases in the percentage of odd-eighth quotes beginning May 27, 1994. This strongly suggests that the market makers in these stocks also shifted their pattern of odd-eighths use simultaneously.

The quote behavior of individual market makers for Intel, as shown in Panel C of Table IV, is very different from Apple or Microsoft. There is no coordinated shift in the way the dealers quote this stock. Rather, almost all of the increase in odd-eighth quotes can be attributed to a single market maker who persistently used odd eighths to narrow the spread. The absence of a coordinated change in quotation practices explains the differences between the muted decline in quoted and effective spreads of Intel and the striking declines in the other four securities.

#### *A.2. Did Market Makers Cease Quoting These Stocks when Spreads Declined?*

If spreads originated from a competitive market prior to the use of odd eighths, the significant reduction in revenues realized in June and July implies that higher-cost market makers would be forced from the market. Alternatively, if the maintenance of a minimum quoted spread of \$0.25 allowed dealers to earn economic profits prior to the use of odd eighths, we would expect them to continue making markets if one-eighth spreads provide adequate compensation.

The finding that effective spreads narrow with the use of odd-eighth quotes suggests a real loss of revenue for NASDAQ dealers and is inconsistent with the hypothesis that the switch to routine use of odd eighths was merely "window dressing" to blunt public criticism of NASDAQ practices. The results for Apple, Intel, and Microsoft in Table IV imply that spreads of \$0.125 have provided adequate compensation for dealers to continue as market makers. Specifically, we find that the number of market makers is unchanged between June 1994 and the end of August 1994 despite the significant loss of revenue associated with the sharp increase in the incidence of odd-eighth quotes. A review of the Bridge Quotation System on August 25, 1994 reveals that all 5 stocks were quoted by more market makers on that day than the latest number of market makers recorded on the 1993 Center for Research in

Securities Prices tape.<sup>7</sup> The continued participation of the market makers is consistent with the hypothesis that spreads that excluded odd eighths did not reflect a competitive equilibrium.

It is also possible that NASDAQ spreads were competitive prior to the switch to odd-eighth quotes, but that dealers responded to narrower spreads by lowering the quality of market-making services and refusing to execute large orders at one price. However, we find that mean trade sizes (not shown) are larger for Cisco Systems, Intel, Apple Computer and Microsoft once all price fractions are used. Tests for differences in means indicate that the increase in trade size is significant at the 5 percent level for Cisco and at the 1 percent level for Intel and Microsoft. The decrease in average trade size of Amgen is not significant.

### *B. Did the Costs of Making Markets Decline in May 1994?*

This section investigates whether the reduction in spreads for these five stocks can be traced to changes in the costs of making markets. Variables found to be associated with trading costs in previous research include volatility, trading volume, and price.<sup>8</sup> In light of the swift change in the levels of the posted and effective spreads, we would expect an abrupt change in one or more of these factors to coincide with the timing of the reduction in trading costs.<sup>9</sup> To assess the importance of price, volatility, and share volume in explaining the decline in spreads, we regress the time series of inside spreads on these three economic variables.<sup>10</sup> We also include a dummy variable that takes the value of 1 for all trading days between May 27 and the end of our

<sup>7</sup> We focus on the total number of dealers since we cannot identify the order flow by market maker. While we might expect an unequal allocation of trades across dealers, the preferencing of trades to dealers away from the inside market implies that all market makers were affected by the change in effective spreads.

<sup>8</sup> The effects of trading activity (measured using volume or the number of trades) and risk on spreads is analyzed in Demsetz (1968), Tinic (1972), Tinic and West (1972), and Stoll (1978). The impact of increases in the level of competition (as proxied by the number of market makers) on spreads is evaluated by Tinic and West (1972), Benston and Hagerman (1974), and Hamilton (1976, 1978).

<sup>9</sup> On May 23, 1994, Microsoft split its stock 2 for 1 and, as a result, the stock price fell almost in half. However, the split was effective Monday May 23, yet the quoted spreads do not narrow until Friday May 27, fully 4 trading days after the split. It was also announced on May 12 that Microsoft would be included in the S & P 500 Index. The actual date of the inclusion in the index was June 6, 1994. Thus Microsoft's spreads fell more than one week prior to the inclusion and two weeks after the announcement.

<sup>10</sup> The narrowing of spreads may result from a decline in share prices. Specifically, the maintenance of relative spreads would require a narrowing of spreads in the face of swift price declines. The decline in spreads may also arise from large increases in share volume, which provide market makers with more opportunities to adjust inventory positions and thereby lower their inventory holding costs. These costs can arise either through the opportunity costs from investing in inventory or from the possibility that prices move against the market maker. Finally, reductions in the volatility of returns might be expected to lower the costs of holding inventory since dealers face reduced risks of large unexpected price movements, independent of the total share volume.

sample period and 0 otherwise. This date corresponds to the first full trading day following the public dissemination of the findings of Christie and Schultz (1994). The regression variables are defined as follows. The dependent variable is the daily time-weighted average inside spread. *Price* is the natural logarithm of the closing price at the end of each trading day. *Volume* is the natural logarithm of the total daily share volume. *Volatility* is the daily standard deviation of half-hour returns computed using the midpoint of the inside spread at the end of every 30 minutes. A significantly negative coefficient for the dummy variable would imply that spreads were lower after May 26 even after controlling for these economic factors.

The results, which are presented in Table V, are remarkably similar across stocks. Aside from Apple Computer, the estimated coefficient for *Price* is

**Table V**  
**Regressions of the Average Inside Spread on Price, Volume, Volatility, and a Dummy Variable for the Public Awareness of the Absence of Odd Eighths**

The dependent variable is the daily time-weighted average inside spread. *Price* is the natural logarithm of the closing price at the end of each trading day. *Volume* is the natural logarithm of the totally daily share volume. *Volatility* is the daily standard deviation of half-hour returns computed using the midpoint of the inside spread at the end of every 30 minutes. *Public* is a dummy variable taking the value of 1 for all trading days beginning May 27, 1994. Each regression uses data from January 1993 through July 1994, excluding July 15, 1994 when NASDAQ experienced difficulties installing new operating software that resulted in numerous locked and crossed quotes. DW refers to the value of the Durbin-Watson statistic. The absolute value of the heteroskedastic consistent *t*-statistics are shown in parentheses. The Microsoft regressions are corrected for autoregressive errors.

| Intercept                      | <i>Price</i>    | <i>Volume</i>    | <i>Volatility</i> | <i>Public</i>     | <i>R</i> <sup>2</sup> | DW   |
|--------------------------------|-----------------|------------------|-------------------|-------------------|-----------------------|------|
| Panel A: Amgen, Inc.           |                 |                  |                   |                   |                       |      |
| 0.489<br>(7.98)                | 0.038<br>(3.36) | -0.023<br>(6.34) | 4.079<br>(3.83)   | -0.147<br>(36.98) | 0.625                 | 1.93 |
| Panel B: Apple Computer, Inc.  |                 |                  |                   |                   |                       |      |
| 0.575<br>(13.04)               | 0.002<br>(0.44) | -0.022<br>(7.29) | 3.605<br>(4.30)   | -0.126<br>(30.87) | 0.706                 | 1.94 |
| Panel C: Cisco Systems, Inc.   |                 |                  |                   |                   |                       |      |
| 0.663<br>(10.76)               | 0.033<br>(6.01) | -0.033<br>(9.73) | 4.100<br>(4.85)   | -0.122<br>(22.29) | 0.783                 | 1.85 |
| Panel D: Intel Corporation     |                 |                  |                   |                   |                       |      |
| 0.479<br>(11.44)               | 0.021<br>(4.92) | -0.019<br>(8.25) | 1.426<br>(1.76)   | -0.026<br>(7.14)  | 0.299                 | 1.73 |
| Panel E: Microsoft Corporation |                 |                  |                   |                   |                       |      |
| 0.524<br>(3.76)                | 0.053<br>(2.17) | -0.030<br>(5.92) | 4.710<br>(2.91)   | -0.094<br>(11.14) | 0.602                 | 2.10 |

significantly positive at the 5 percent level, implying that higher prices are associated with wider inside spreads. The estimated volume coefficients are all negative and significant at the 1 percent level, implying that narrower inside spreads are associated with heavier trading volume. In addition, the coefficient for our volatility measure is consistently estimated as positive and significant at the 1 percent level (with the exception of Intel), signifying that increases in volatility are associated with wide spreads. Thus, the regression evidence provides strong support for the ability of the economic variables to explain the variation in spreads through time. However, they do not explain the abrupt narrowing of spreads, since the coefficient for the dummy variable is negative and highly significant in each regression, with 4 of the *t*-statistics exceeding 10.

To summarize, this evidence suggests that the rapid and unprecedented decline in spreads for these stocks is not explained by any of these economic factors. This conclusion is supported by the absence of a change in either the quoted or effective spreads for the 5 remaining stocks in Table I that we do not study since they were routinely quoted in odd eighths prior to May 1994.

#### **IV. Conclusions**

On Friday May 27, 1994, the average inside spread for Amgen, Cisco Systems, and Microsoft fell to approximately \$0.15 per share after varying between \$0.25 and \$0.45 during the preceding 17 months. The following trading day, the mean inside spread for Apple Computer fell below \$0.20. It narrowed further on Wednesday June 1 to approximately \$0.13. Like the other stocks, Apple Computer's spread had not narrowed to less than \$0.25 in the preceding 17 months. The collapse in the effective spreads for each stock mirrored the change in quoted spreads, falling by over 40 percent during the same trading sessions.

This article attempts to identify the source of this simultaneous reduction in trading costs for four stocks that were already among the largest and most actively traded issues in the NASDAQ National Market System. We find no evidence that the reduction in spreads is explained by changes in the costs of market making. Instead, the decrease in transactions costs can be directly traced to a fundamental shift in the use of odd-eighth quotes. Prior to May 27, 1994, odd-eighth quotes were exceedingly rare for each of these stocks. However, once odd-eighth quotes were introduced on May 27 for Amgen, Cisco, and Microsoft and on May 31 for Apple Computer, the proportion of one-eighth spreads immediately rose from almost zero to over 50 percent, and effective and quoted spreads fell by almost 50 percent.

In light of these findings, this article asks why odd eighths were not used to quote these stocks prior to the end of May 1994 and what prompted the divergence from what had become a strong historical precedent? The answer appears to rest with the collapse of an implicit pricing agreement among the market makers to avoid odd-eighth quotes in these stocks. This collapse was

precipitated by newspaper articles on May 26 and 27 describing the results of Christie and Schultz (1994) who question the degree of competition between NASDAQ dealers who quote stocks exclusively in even eighths. These articles closely followed a reported threat of regulation by the NASD in a meeting with market makers on May 24. The results in this article suggest that for Amgen, Apple, Cisco Systems, and Microsoft, the abandonment of the implicit agreement was complete. The number of dealers using odd eighths for at least 40 percent of their quotes increased from 0 on May 26 to over 40 by June 2 for each stock. In contrast, the implicit agreement among the market makers in Intel appears to have remained intact. However, beginning June 6, 1994, a lone market maker began to undercut the spreads of other dealers by posting odd-eighth quotes, thereby causing the modest decreases in the quoted and effective spreads that we observe.

The observation that effective spreads and quoted spreads collapsed simultaneously indicates that the appearance of odd-eighth quotes was not merely "window dressing." Specifically, if these hidden quotes were routinely used to execute trades prior to May 27, 1994, we would not have observed the sudden and dramatic decline in effective spreads. An alternative explanation for our findings is that spreads of at least \$0.25 were necessary to compensate dealers for the risks of making markets in these stocks, but that market makers reduced spreads below their competitive levels in reaction to the negative publicity. Under the hypothesis that the spreads were competitively determined prior to May 27, the reductions in revenue would be expected to result in losses for higher cost suppliers. Yet, we do not observe any decline in the number of market makers for any of these stocks through August 1994. This suggests that either the reduced revenues continue to yield sufficient profits, or that market makers are willing to absorb losses to forestall regulatory action. However, this latter explanation is also problematic, since it implies that if dealers were not implicitly colluding to set prices prior to May 27, 1994, they did engage in price coordination afterward.

The fundamental premise of the NASDAQ system is that market makers compete for orders through prices, and this competition for order flow produces the best order execution for investors. However, it is difficult to reconcile this competitive model with the finding that trading costs decline by almost 50 percent in the absence of any apparent change in the costs of market making. Further, the continued participation of dealers in markets after this decline in their revenues contradicts the premise that spreads were determined through competition before May 27, 1994. Finally, it is especially difficult to understand why, in a competitive market, over 40 dealers simultaneously changed a pricing practice that had been in effect for years only after the practice was made public.

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