Regulatory and Legal Pressures and the Costs of Nasdaq Trading

Paul Schultz

University of Notre Dame

January, 2000

Preliminary. Comments welcome.

I have received financial support for this project from a Dean's Summer Fellowship at Ohio State University and the Charles A. Dice Center for Financial Research at Ohio State. I have been retained by the plaintiffs in the Nasdaq antitrust litigation, but this research was not sponsored in whole or in part by them. Helpful comments were provided by William Christie, Lawrence Glosten (the editor), Roger Huang, David Hyland, Randall Kroszner, Timothy McCormick, Jennifer Quinn, an anonymous referee and seminar participants at The University of Chicago, Northwestern University, The University of Texas at Arlington, and Vanderbilt University. They do not bear any responsibility for any errors or shortcomings of this study.

Abstract

The Nasdaq market came under intense pressure from regulators and class-action lawsuits following allegations of tacit collusion by Christie and Schultz (1994). This paper examines the changes in transactions costs on Nasdaq over January 1993 through June 1996 using 16 million trades in 30 stocks. Effective spreads cannot be estimated during 1995 and 1996 because time-stamps of trades and quotes cannot be matched. However, the autocovariance spread estimator of Roll (1984) works well with intraday data over this period. Using this spread estimator, I find that trading costs declined significantly for 29 of the 30 stocks over 1993-1996. Moreover, trading costs fell for trades of all sizes.

The Nasdaq stock market came under intense scrutiny from regulators, academics, and the press during 1994 and 1995. The catalyst for this attention was the academic study by Christie and Schultz (1994) that documents an almost complete absence of quotes using odd-eighth (1/8, 3/8, 5/8, 7/8) price fractions for 70 of 100 active Nasdaq stocks during 1991. The authors' statement that the most likely explanation for the absence of odd-eighth quotes was implicit collusion among Nasdaq dealers to maintain bid-ask spreads of at least 25¢ generated numerous articles about the study in the popular press. These articles led to the immediate filing of numerous class action lawsuits on behalf of investors in Nasdaq stocks. Investigations of Nasdaq by the U.S. Department of Justice and the Securities and Exchange Commission (SEC) followed.

In this paper, I use all intraday trades and quotes for 30 Nasdaq stocks over the entire January 1993 through June 1996 interval to examine how the costs of trading on Nasdaq changed while the market was under legal and regulatory pressure. In doing this I confront methodological issues of importance to any researcher using intraday Nasdaq data from this period. I show that during part of 1995 and 1996 time stamps for Nasdaq trades and their contemporaneous quotes differed by several minutes. The non-synchroneity of quote and trade time-stamps remains even after all late reported trades (see Porter and Weaver (1998)) are discarded and is caused by a delay in applying time stamps to trades. The effect of this non-synchroneity is that estimates of effective spreads are inaccurate and typically severely upwardly biased. Thus most of the results reported here are based on the Roll (1984) autocovariance estimator, an alternative method of measuring trading costs that is based solely on trade prices. Although the Roll (1984) spread estimator has been shown to perform poorly with daily data, I find that it works surprisingly well with intraday trade prices and can be used when time stamps for trades and quotes cannot be matched. In addition, I show that it is possible to use the Roll estimator to simultaneously calculate different effective spreads for trades that differ by size or other characteristics.

By using the Roll estimator of trading costs I am able to show that per-share costs declined for 29 of the 30 sample stocks over 1993 through June 1996. For most stocks, trading costs began to decline between the time that the civil suits were filed and the Department of Justice announced its investigation, and continued to fall over the next two years. Trading costs appear to have initially declined mainly for large stocks and later for small stocks. For ten of the sample stocks, Roll spreads fell by more than 50%. Commissions remained the same or fell over this period so total trading costs facing investors declined. I also show that spreads fell by similar proportions for trades of all sizes. Large traders as well as small seem to have benefitted from the recent regulatory pressure on Nasdaq.

The remainder of the paper is organized as follows. In the first section I discuss civil suits against Nasdaq market makers and the investigations of the market by the Department of Justice and the Securities and Exchange Commission. In section II the benefits and drawbacks of various ways of estimating trading costs are explored. Section III documents changes in trading costs on Nasdaq over 1993 - 1996. Section IV summarizes the results of this paper and offers concluding comments.

I. Regulatory and Legal Pressures on the Nasdaq Market

On May 26th 1994, the Los Angeles Times carried the first article in the popular press discussing the finding by Christie and Schultz (1994) of an almost complete absence of quotes ending in odd-eighths for 70 of the 100 largest Nasdaq stocks during 1991. Popular interest in the academic study was aroused by the authors' statement that the likely reason for the absence of odd-eighth quotes was an understanding or tacit agreement among dealers to maintain wide spreads. Within the next few days, several other newspapers also carried articles on the study and its allegations of collusion among dealers. Class-action lawsuits were filed on behalf of investors in Nasdaq securities almost immediately after stories about the Christie-Schultz study appeared in the popular press. Eventually, over thirty civil suits were filed on behalf of classes of individual investors and even the State of Louisiana. These suits were consolidated later in 1994.

There was little additional pressure on the NASD or Nasdaq market makers for most of 1994. Then, in a bombshell announcement on October 19th 1994, the U.S. Department of Justice revealed an investigation into "alleged price-fixing" on Nasdaq. This was followed by an announcement by the U.S. Securities and Exchange Commission on November 14, 1994 that they were launching their own investigation of anticompetitive practices on Nasdaq. In response to these pressures, the NASD announced at the same time that it would appoint an outside panel to review the operation of the Nasdaq market.

Little was revealed publicly about the ongoing investigations of the Nasdaq market over the next few months. There is, however, evidence that market makers were coming under pressure to narrow spreads. The Wall Street Journal of November 17, 1994 claimed that as a result of the glare of the Department of Justice investigation, Nasdaq dealers had been quietly tightening spreads for the largest and most visible Nasdaq stocks. A Wall Street Journal story of February 21, 1995 said that senior Nasdaq officials were talking to the heads of several large Wall Street firms about restructuring the market. The talks were believed to be focused on narrowing spreads. An additional story on March 14th, 1995 noted that the Nasdaq stock market was working behind the scenes to improve spreads before regulators finished studying the market. The Nasdaq market's incentive for putting pressure on the dealers is clear. In July of 1995, it was revealed that that the SEC was considering filing a disciplinary case against the NASD for failing to prevent abuses of the Nasdaq market by its dealers.

Additional pressure on Nasdaq spreads came from the possibility of losing firms to the New York Stock Exchange (NYSE) or American Stock Exchange (Amex) as a result of Nasdaq's adverse publicity. In an advertising campaign aimed at snaring Nasdaq companies, the American Exchange noted that the stock of almost every publicly traded brokerage firm was listed on an exchange. Market makers' preference for listing their own stocks on the NYSE was also discussed in Barrons.

Around the end of 1995, it became clear that major reforms were indeed coming. In September, the independent blue-ribbon commission headed by former senator Warren Rudman issued a report that criticised the way that the market policed its dealers. It advocated splitting off the regulatory functions of the NASD from the Nasdaq market. It also called for more public representation on the NASD's board. NASD member firms approved an overhaul of the Nasdaq market in January 1996.

The investigations of Nasdaq by the U.S. Department of Justice and the SEC were winding down by mid-1996.The Wall Street Journal reported on June 18, 1996 that the SEC was pushing for a settlement with the NASD in which the NASD would agree that it had repeatedly failed to enforce market rules. In the proposed settlement the NASD would be censured but not fined for their actions.

It is impossible to predict exactly when transactions costs might be affected by the pressure on Nasdaq. In this paper, I examine trading costs in four separate periods. The first is from January 1993 through May 26, 1994. This is before the publicity about the Christie-Schultz findings. The second period is from the first newspaper accounts about possible collusion on Nasdaq until the Department of Justice announced their investigation in October 1994. The third period that I examine is from October 1994 until the NASD members voted to restructure the market on January 11, 1996. The fourth period runs from January 1996 through June 1996.

II. Estimating Trading Costs

A. Sample and Data

Trading costs are estimated using intraday trades and quotes for 30 Nasdaq stocks from January 1, 1993 through June 30, 1996. The advantage of using only 30 stocks is that a detailed examination of trading costs is possible. Transactions costs are estimated using all of the more than 16 million trades in these stocks over 1993 through June 1996. The consistency of the results across sample stocks suggests that the findings of this paper can be extrapolated to Nasdaq stocks as a whole.

To pick the sample stocks, I first obtained the market capitalizations of all Nasdaq stocks at the end of 1993 from the CRSP tapes. I then selected three groups of sample firms based on end of 1993 size. The large firm sample consists of the ten largest stocks at the end of 1993. The medium-size firm sample is the 101st-110th largest stocks at this time. All of these 20 stocks were listed continuously on Nasdaq over the sample period. The small firm sample consists of the ten stocks from among the 301st-314th largest stocks at the end of 1993 that were listed on Nasdaq continuously from the beginning of 1993 through 1996. Although they are defined as small in this paper, these stocks are much larger than most Nasdaq stocks. Sizes are defined as of the end of 1993 because that is the last year-end before regulatory and legal pressure was brought to bear on Nasdaq.

Intraday quotes and trades are obtained from the New York Stock Exchanges' Trade and Quote (TAQ) data. In the estimation of effective spreads that follows, all trades marked late are omitted, as are trades reported with errors. I also omit trades that occur before 9:30 a.m. or after 4pm.. In estimating effective spreads, trades are also omitted if the contemporaneous quoted spread is more than $2.50.

Table 1 identifies the sample stocks and provides a brief description of them. The firm name and ticker symbol are reported in the first two columns. The next four columns provide market capitalizations in thousands of dollars at the end of 1992, 1993, 1994, and 1995. Each of the ten large stocks were among the largest Nasdaq stocks for the whole sample period. The ten medium-size firms have market values that are an order of magnitude smaller than the large firm market values. The small firms have market values that are one-fourth to one-third that of the medium firms. Survivorship biases from restricting the small firm sample to stocks that were on Nasdaq the entire sample period do not seem to be important. One of the small stocks, Peoplesoft, quintupled in value from the end of 1993 through the end of 1995. Three of these firms shrank to less than half their 1993 value by the end of 1995. All in all, five of the small stocks grew in value between the end of 1993 and the end of 1995 and five shrunk. As we will see, the returns of sample stocks varied widely over the sample period, but trading costs declined for almost all stocks, regardless of whether they were winners or losers.

The last column of Table 1 reports the mean number of trades per day over the entire three-and-one-half year period. The large firm stocks trade frequently. Intel averages over 4,000 trades per day (more than 10 per minute) and Microsoft averages over 2,600 trades per day. In general, the medium-size firms have far fewer trades, with several averaging around 100 per day. There are exceptions though. Cirrus Logic averages almost 900 trades per day while Hon Industries averages 17. Small stocks have even fewer trades. Two of the stocks average less than 10 trades per day. Peoplesoft is the most active with 217.6 trades per day.

B. Quoted Spreads

Spreads between quoted bid and ask prices provide a useful measure of the maximum price that an investor would expect to pay for a small round-trip transaction. Figure 1 depicts mean quoted spreads for large, medium, and small stocks at the end of each month from January 1993 through June 1996. Each month a simple (not time-weighted) average of all quoted spreads is calculated for each stock. A grand mean for each size category is calculated as a simple average of the individual firm averages. As expected quoted spreads are widest for the small stocks, narrower for the medium stocks, and narrowest for the large stocks. Quoted spreads decline for stocks of all sizes over this period.

Spreads of large firms decline abruptly in June 1994. Christie, Harris and Schultz (1994) document the decline in spreads for Microsoft, Amgen and Cisco Systems and show that the changes were brought about by a simultaneous adoption of odd-eighth quotes by almost all of these stocks' market makers following publicity about the Christie and Schultz (1994) claims of tacit collusion on Nasdaq. They find a similar shift to odd-eighths and decline in spreads for Apple Computer, which is not in this paper's sample. Reports produced later by the SEC indicate that market makers met at Bear Stearns headquarters in New York on May 26th and discussed reducing spreads in some of the most visible Nasdaq stocks.

A problem with quoted spreads is that trades are frequently executed within the quotes. For example, Bessembinder and Kaufman (1997) examine a sample of 300 Nasdaq stocks over 1994 and find that 26.9% of trades were executed within the spread. They also report, as do Christie, Harris, and Schultz (1994), that larger trades are even more likely to be executed within the quotes. An additional limitation of quoted spreads is that they apply only to small trades. The minimum quote size for Nasdaq stocks was 1,000 shares for the most active stocks and 500 or 200 shares for less active stocks during the period of this study. Larger trades could be executed outside the spread as well as within it.

C. Effective Spreads

A measure of transactions costs that allows for trades within or outside the quotes is the effective spread. The effective spread for trade t is twice the absolute value of the difference between the trade price and the contemporaneous bid-ask midpoint. That is,

$$Effective\ Spread_t = 2 \cdot \left| P_t - \frac{B_t + A_t}{2} \right|$$

$$\begin{aligned} Where\ P_t &= the\ price\ of\ trade\ t \\ B_t &= the\ inside\ bid\ price\ when\ trade\ t\ took\ place \\ A_t &= the\ inside\ ask\ price\ when\ trade\ t\ took\ place. \end{aligned} \quad (1)$$

Because the effective spread explicitly allows for trades within or outside the quotes, it is a popular measure of trading costs. Researchers typically use a mean effective spread calculated across many trades as a transactions cost measure. Papers that employ effective spreads as a measure of trading costs for Nasdaq stocks include Barclay (1997), Bessembinder (1999), Bessembinder and Kauffman (1997), Christie, Harris, and Schultz (1994), Christie and Huang (1995), Goldstein and Nelling (1999), and Huang and Stoll (1996).

Despite its appeal, the effective spread estimator of trading costs is seriously flawed for Nasdaq stocks during some periods. The standard source of intraday data for academic work, TAQ, includes time stamps for both trades and quotes, but time stamps are not entered when trades are executed or when the quotes are updated. Instead, they are supplied by the Securities Industry Automation Corporation (SIAC) when the reported trade or quote update reaches their computers for processing. Nasdaq trades and quotes are disseminated separately through the Nasdaq Quote Dissemination System (NQDS) and the Nasdaq Trade Dissemination System (NTDS), so there are different delays in quote and trade time stamps. During parts of 1995 and 1996, trade time stamps were delayed several minutes longer than quotes. A researcher who matches Nasdaq trades and quotes using the provided time stamps may severely overestimate effective spreads.

The TAQ data does not provide any information that can be used directly to see if trades are being correctly matched with quotes. However, all stocks in our sample have quote sizes of at least 200 shares (for most it is 1,000 shares). Indirect inferences about mismatched time stamps are obtained by comparing trade prices with matched quotes for trades of 200 shares or less. A trade price that is less than the bid price or greater than the ask price indicates incorrectly matched trades and quotes.

Figure 2 shows the proportion of small trades outside the quotes for large, medium, and small stocks for each month over the January 1993 through June 1996 period. The proportion is small, around 1%, for all groups of stocks for each month during 1993 and 1994. Market makers have 90 seconds to report a trade, and it is possible that many of these trades occurred immediately prior to a quote change. However, starting in early 1995, the proportion of trades outside the quotes increases rapidly for all stocks, but particularly for large stocks. It reaches over 12% of trades for large stocks in early 1996.

These are **not** trades that were reported late. I deleted those trades from my sample. Thus there is no indication in the TAQ data to alert the researcher to potential problems.

New York Stock Exchange officials tell me that the mismatching of trade and quote time-stamps was particularly severe in 1995 and early 1996 because trading volume was too high for SIAC's computer system. To test this, I regress PCT_t, the percentage of all trades of all sample stocks outside the quoted spread on day t on $TRADES_t$, the number of trades (in thousands) in all sample stocks, and dummy variable D_{1t}, D_{2t}, D_{3t}, and D_{4t} that take values of 1 if there are more than 10,000, more than 20,000, more than 30,000 or more than 40,000 trades in the sample stocks on day t. The regression estimate is

$$\underset{}{PCT_t} = \underset{(-3.73)}{-1.57} + \underset{(9.67)}{0.288}\ TRADES_t \underset{(-3.17)}{-1.18}D_{1,t} \underset{(0.17)}{+0.07}D_{2,t} \underset{(1.82)}{+0.76}D_{3,t} \underset{(2.18)}{+1.56}D_{4,t} + \varepsilon_t \qquad (2)$$

T-statistics are shown in parentheses under the coefficients. As expected, the percentage of trades outside the quotes on a given day is positively and significantly related to the number of trades on that day. The function is nonlinear, with the percentage of trades outside the quotes increasing at an increasing rate with the number of trades when the number exceeds 20,000. This is consistent with trade reporting being delayed when the number of trades during a short period of time exceeded a threshold level. Another finding (not shown) that is consistent with this is that the proportion of trades outside the quotes is highest in the morning, drops to its lowest in early afternoon and then rises slightly around the close.

Figure 2 contains perhaps the strongest evidence that volume that is too heavy for the computer systems to handle causes trades outside of the quotes. In Figure 2 the proportion of trades outside the quotes drops abruptly in March 1996. This corresponds to an increase in the capacity of Nasdaq's computer and reporting facilities.

The proportion of trades that lie outside the quotes is a lower bound on the number of trades that are not correctly matched with synchronous quotes. It is easy to think of examples where a trade price of, say, $24 1/8 occurs when $24 1/8 is the bid price, but the trade is matched with quotes from a different time when $ 24 1/8 was the midpoint or the ask price. While a large proportion of trades outside the quotes implies mismatched time stamps, a small proportion of trades outside the quotes does not necessarily mean that time stamps match.

It appears to be impossible to find the actual quotes in effect when trades took place. The researcher cannot simply look to the previous quote that contained the price of the trade in question. I have found many cases where there is no quote that contains the trade price in the previous fifteen minutes. With potential mismatches of time stamps of fifteen minutes, there may be several possible quotes (with different bid and ask prices) that are consistent with a given trade. Because the lag between quote and trade time stamps varies, I find that simple rules like adding 5 seconds or 20 seconds to the quote time actually increase the number of trades outside quotes.

The effect of mismatched time stamps on the measurement of effective spreads is apparent when daily effective spreads for individual stocks are examined. Figure 3a shows mean daily effective spreads for Microsoft for the sample period while Figure 3b shows mean daily effective spreads for Intel. On some days during the periods when trade and quote time-stamps do not match up well, measured mean effective spreads for Microsoft or Intel exceed 40¢, far more than the quoted spreads. It is clear that mismatched quote and trade time stamps can produce very large measurement errors.

Note that the papers mentioned above that calculate effective spreads for Nasdaq stocks use data from before 1995. Their results are not influenced by this problem. Effective spreads can be calculated accurately prior to 1995 and are the preferred measure of trading costs during this period. It is only starting about March 1995 that it is impossible to match Nasdaq trades and quotes from TAQ data. This makes it impossible to estimate effective spreads accurately during 1995 and 1996. This is precisely the time when Nasdaq market makers were under legal and regulatory pressures to narrow spreads. Alternative estimators are needed.

D. The Roll Spread Estimator

It has long been recognized that if trades fluctuate between bid and ask prices, returns will be negatively autocorrelated. Roll (1984) uses this property of transactions prices to derive an estimator of the implicit bid ask spread. With P_t as the price of transaction t, Q_t =1 for buy orders and -1 for sell orders, μ as the expected price change, S as the effective spread and ε_t as the unexpected change in the stock's true value, the change in prices between two successive trades is:

$$\Delta P_t = P_t - P_{t-1} = \frac{1}{2}(Q_t - Q_{t-1})S + \mu + \varepsilon_t. \qquad (3)$$

Note that we are using the prices at which trades actually take place. The difference in these prices is the effective spread. Over the short time intervals between trades we can assume the expected price change μ is zero. Thus, E(ΔP)=0 and

$$COV(\Delta P_t, \Delta P_{t-1}) = \frac{1}{4}E[(Q_t - Q_{t-1})(Q_{t-1} - Q_{t-2})S^2] + \frac{1}{2}E[(Q_t - Q_{t-1})S\varepsilon_{t-1}] + \frac{1}{2}E[(Q_{t-1} - Q_{t-2})S\varepsilon_t] + E[\varepsilon_t \varepsilon_{t-1}]. \quad (4)$$

In deriving his spread estimator Roll (1984) makes several assumptions:

(i) Successive trade types (buys or sells) are independent. That is, $E(Q_t Q_{t-1}) = 0$.

(ii) The spread is constant.

(iii) Trade types do not contain information about future changes in value. That is

$$E[\varepsilon_t(Q_{t-1} - Q_{t-2})] = 0. \qquad (5)$$

(iv) Changes in the true value do not contain information about future trades:

$$E[\varepsilon_{t-1}(Q_t - Q_{t-1})] = 0. \qquad (6)$$

(v). Innovations in the true value of the stock are independent. That is,

$$E[\varepsilon_t \varepsilon_{t-1}] = 0. \qquad (7)$$

Then,

$$COV(\Delta P_t, \Delta P_{t-1}) = \frac{1}{4} E[Q_t Q_{t-1} S^2 - Q_t Q_{t-2} S^2 - Q_{t-1}^2 S^2 + Q_{t-1} Q_{t-2} S^2]. \qquad (8)$$

and independence of successive trades implies that

$$COV(\Delta P_t, \Delta P_{t-1}) = -\frac{1}{4} S^2. \qquad (9)$$

Or,

$$S = 2\sqrt{-COV(\Delta P_t \Delta P_{t-1})}. \qquad (10)$$

This provides Roll's spread estimator

$$Roll\ \ Spread = 2\sqrt{\frac{-\sum_{t=1}^{T} \Delta P_t \Delta P_{t-1}}{T-1}}. \qquad (11)$$

Like the effective spread estimator, the Roll estimator is based on prices that investors actually pay rather than quoted prices. However, an important advantage of a Roll estimator is that there is no need for contemporaneous quotes to measure transactions costs. As long as trades are reported in order, the time stamp is irrelevant.

The Roll estimator has been used with closing trade prices to estimate trading costs in several studies. It has performed poorly, generating undefined spread estimates almost half of the time. However, Harris (1990) shows that the Roll estimator may be ill-suited for use with daily data. For daily returns, the variance of price changes is far larger than the covariance. Even with one year of data, covariances cannot be estimated with any degree of accuracy. However, as I show here, over the shorter periods of time available with intraday data the covariance of price changes is large relative to the variance of price changes and spreads can be estimated much more accurately. Huang and Stoll (1996) also use Roll spread estimates based on intraday data. They report estimates for Roll spreads that are similar to other measures of trading costs.

Several refinements to the Roll estimator are possible. Roll (1984) points out that the simple version of the Roll estimator is biased downward in small samples as a result of Jensen's inequality. The covariance of successive price changes is measured with error. The square root function, which is applied to the estimated autocovariance is a concave function. Thus,

$$E(Roll\ \ Spread) \ = \ E\left(2\sqrt{\frac{\sum_{t=1}^{T} \Delta P_t \Delta P_{t-1}}{T-1}} \right) \ < \ 2\sqrt{E\left(\frac{\sum_{t=1}^{T} \Delta P_t \Delta P_{t-1}}{T-1} \right)} \ = \ S. \qquad (12)$$

Roll (1984) appeals to asymptotic arguments to derive the expected value of the estimator. With n observations and a kurtosis of κ[1]

$$E(Roll\ \ Spread) \ = \ Spread \left[1 \ - \ \frac{(\kappa \ - \ 3) \ + \ 7}{8(n \ - \ 1)} \right]. \qquad (13)$$

Thus a simple estimator that I use here that is based on Roll's expected value of the estimator and the assumption of normally distributed returns is

$$Adjusted\ \ Roll\ \ Spread \ = \ \frac{Roll\ \ Spread}{1 \ - \ \frac{7}{8(n-1)}}. \qquad (14)$$

There are obvious problems with this estimator. First, I am using an asymptotic estimator to make small sample adjustments. I am also assuming that the kurtosis of the price change is 3, the value of a normal distribution. The great virtue of this adjustment for Jensen's inequality is its simplicity. As we will see, it produces estimates that are close to the effective spreads during periods when quote and trade time stamps allow accurate estimation of effective spreads.

E. A Comparison of Roll Spreads with Effective Spreads

Table 2 provides mean daily effective spreads, mean daily Roll spreads, mean daily Roll spreads adjusted for Jensen's inequality, and regressions of Roll spreads on effective spreads for each stock for the period from January 1993 through February 1995. The purpose of this table is to compare effective spreads with Roll spreads when effective spreads can be estimated accurately. The February 1995 ending date is chosen by examining Figure 2 and determining that this avoids months with a lot of mismatched trade and quote time stamps.

Panel A of Table 2 shows that the mean Roll spread estimates are very close to the mean effective spread for large stocks. Although t-statistics indicate that differences between effective spreads and Roll spreads are significant for seven of the ten large stocks, the differences are always less than 1/2¢. Seven of the ten are within 1/5¢. Since the number of trades on a given day is usually large, we would expect adjustments for Jensen's inequality to have little effect on spread estimates and this is confirmed in Table 2.

For medium-size firms (Panel B) and small firms (Panel C), adjusting for the bias from Jensen's inequality moves Roll spread estimates closer to effective spread estimates. Mean Roll spreads are less than mean effective spreads for each of the ten medium-size firms and each of the ten small firms. After the Jensen's inequality adjustment, nine of the ten medium-size firms and six of the ten small firms have mean adjusted Roll spread estimates within 1.5¢ of the effective spread estimates. The Roll spreads are still usually smaller than the effective spreads, a difference that, as we will see, might be attributed to serial dependence of the trade type.

The standard deviation of the daily mean effective spread and the daily mean of the adjusted Roll spreads are shown in the fifth and sixth columns of Table 2. The standard deviation of the adjusted Roll spread exceeds the standard deviation of the effective spread for all sample stocks when transactions costs are estimated daily. This implies greater estimation errors for the Roll spread than the effective spreads, particularly for small and medium-size firms. However, this disadvantage of the Roll estimator may be minimized by simply estimating trading costs over longer time periods than one day.

The next column provides the number of days for which a Roll spread could not be estimated either because the estimated autocovariance of prices is positive or because there were fewer than three trades. The number of days in which the autocovariance is positive is in parentheses. In contrast to the results of Roll (1984) with daily data, positive spread estimates can usually be obtained with only one day of data. For the large active stocks in the sample, there is only one missing estimate out 5,450. The less actively traded stocks have more days when a Roll spread cannot be obtained.

The last three columns of Table 2 report ordinary least squares regressions of the daily adjusted Roll spread estimator on the daily mean effective spread for the period from January 1993 through February 1995. If the adjusted Roll spread estimator is an unbiased predictor of the effective spread, we would expect the slope coefficient to be one and the intercept to be zero. For the large firms, the coefficents on the effective spread range from .8964 for Telecommunications A to 1.1119 for Amgen. Based on T-statistics estimated with White's heteroskedasticity-consistent estimator, four of the coefficients are significantly greater than one, two are significantly less than one, and four are not statistically different from one. R^2's for these regressions range from .5197 for Tellecommunications to .9467 for Microsoft. Daily differences in effective spreads are captured well by Roll spreads.

Standard deviations of the residuals (not shown) range from 1.21¢ to 2.76¢. Thus for all of these stocks, 95% of the adjusted Roll spreads could be found within 5.5¢ of the mean effective spread and for most stocks, the difference in spread estimates is much smaller. All in all, the Roll spread estimate is a close substitute for effective spreads for large firms, even with estimation periods as short as one day.

Regressions for the medium-size and small firms suggest that the Roll spreads are not as close a substitute for effective spreads as for the large stocks. Slope coefficients from the regression of the Roll estimator on the mean effective spread range from .6284 to .9517. Most are above .85, but six of the ten are significantly less than one. R^2's for these regressions range from .1713 for the inactive Hon Industries (HONI) to .6800 for Lone Star Steakhouse (STAR). Most of the regressions have residual standard deviations in the .04 to .0625 range. Thus for most of these stocks, the adjusted Roll spread lies within 12.5¢ of the mean effective spread on 95% of the days. Slope coefficients are significantly less than one for five of the ten small firms. R^2's for these regressions range from .0719 for Citizens Banking Corp (CBCF) to .6506 for Amtech

(AMTC). The standard deviations of the regression residuals are large, with three greater than 30¢.

Table 3 replicates Table 2's comparison of daily mean effective spreads with daily adjusted Roll Spreads, but uses data from March 1995 through June 1996 when Figure 2 indicates that many trades were executed outside the quoted spread. Recall that during the earlier period mean effective spreads and mean adjusted Roll spreads were very similar for the large firms. For each of the ten large firms, the difference was less than .5¢. In this latter period, the Roll spread is 1.41¢ less than the effective spread for Intel, 1.98¢ less for Microsoft, 1.43¢ less for Oracle, and 3.00¢ less for Cisco Systems. Thus Roll spreads do not have the upward bias imparted to effective spreads by the mismatching of trade and quote time stamps. It is also telling that the standard deviations of the daily adjusted Roll spread estimates are less than the standard deviations of the daily mean effective spreads for these three stocks. This implies that the effective spreads are noisier than the adjusted Roll spread estimates.

These results are encouraging. It is during this period that mismatched trades and quotes result in overestimates of effective spreads for large firms. It appears that the adjusted Roll spread estimator provides a less biased and more accurate estimate of trading costs for large firms during this period.

Figure 4 shows daily effective spreads (solid lines) and Roll spreads (triangles) for Cisco Systems for the entire period from January 1, 1993 through June 30, 1996. In 1993 and early 1994, the Roll spread estimator and the effective spread are close, but the Roll spread appears to be estimated with greater error. There is a dramatic decline in both effective spreads and Roll spreads in May 1994 when Nasdaq market makers began using odd-eighths to quote the stock.[2] The most dramatic feature of Figure 4 though is the increase in the level and volatility of effective spreads in late 1995 and early 1996. This is of course the time when time stamps on quotes and trades are most seriously mismatched. During this time Roll spread estimates remain near their earlier levels. They are on average much smaller than the effective spreads and much less volatile. Roll spreads remain consistently below effective spreads through the end of the sample period.

Note though that the Roll spreads in Figure 4 are still more volatile from mid-1995 on than they had been previously. It is possible that trades may have been reported out of order during this busy period. Trades reported out of order typically result in large price changes followed by large reversals, and thus the Roll spread estimates, while apparently less biased than the effective spreads, may still be upwardly biased.

Results are more ambiguous for medium-size and small firms, but panels B and C of Table 3 suggests that the Roll spread estimators are a significant improvement over effective spreads for some stocks. For two of the most active medium firms, Compuware Corp. (CPWR) and Cirrus Logic (CRUS), the standard deviation of the daily mean effective spread is greater than the standard deviation of the adjusted Roll spread. This is also true for the most active of the small firms, Peoplesoft. Again, this suggests that the effective spread estimates are noisier than Roll spread estimates for these stocks. In contrast, during the earlier period the daily mean effective spread has a lower standard deviation than the Roll estimator for all stocks.

The last three columns of Table 3 repeat the regressions of adjusted Roll spreads on effective spreads but now use data from March 1995 through June 1996. During this period, slope coefficients are much lower than one for the large firms. This is especially true for Intel, Microsoft, Oracle, Cisco Systems and Amgen; stocks with Roll spreads that are much lower than the mean effective spreads. The lower coefficient is consistent with an errors-in-variables problem for effective spreads. Slope coefficients decline for medium-size and small firms as well. It is revealing that the coefficients decline most for Cirrus Logic and Peoplesoft, the most active medium-size and small stocks.

F. Why does the Roll Estimator Work So Well?

The Roll spread is employed in this paper to test whether the costs of trading changed over 1993-1996. Even if the Roll estimator is biased it can fulfill this objective as long as it is unaffected by the change in volume in 1995. Figure 4 suggests that the Roll spreads, unlike effective spreads do not change dramatically during the heavy volume periods of 1995.

It is intriguing though that the Roll spread estimates are so close to the effective spread estimates. Indeed, for large stocks the two estimators produce almost identical measures of trading costs. This is surprising because the Roll estimator is based on strong assumptions that are unlikely to be met in practice. To show why the Roll estimator works so well, I now examine the large-sample biases from these questionable simplifying assumptions and show that they are more or less offsetting.

One of these assumptions is that consecutive trade types are independent. I now consider the general case of $E(Q_t Q_{t-1}) = \alpha$, where $-1 < \alpha < 1$. A second objectionable assumption is that the spread is constant. I now more accurately assume that S varies from trade to trade but is serially uncorrelated and uncorrelated with α. Finally, the Roll estimator assumes that trade type is independent of future price changes, or, equivalently, that trades do not contain information. I now more realistically assume that

$$E[\varepsilon_t(Q_{t-1}S_{t-1} - Q_{t-2}S_{t-2})] = [\delta/2]\bar{S} > 0 \qquad (15)$$

We are concerned with how well the Roll spread estimates the mean effective spread $\bar{S}$ when the earlier assumptions used to derive the Roll spread estimator are violated. Asymptotically,

$$\underset{T\to\infty}{Plim}\ (Roll\ Spread\ Estimate)$$

$$= \underset{T\to\infty}{Plim}\ 2\sqrt{\frac{-\sum_{t=1}^{T}\Delta P_t \Delta P_{t-1}}{T-1}},$$

$$= \underset{T\to\infty}{Plim}\ 2\sqrt{\frac{\sum_{t=1}^{T} -1/4[(S_tQ_t - S_{t-1}Q_{t-1})(S_{t-1}Q_{t-1} - S_{t-2}Q_{t-2})] - 1/2[Q_{t-1}S_{t-1} - Q_{t-2}S_{t-2}]\varepsilon_t}{T-1}},$$

$$= \underset{T\to\infty}{Plim}\ \sqrt{\frac{\sum_{t=1}^{T}[-Q_tQ_{t-1}S_tS_{t-1} + Q_tQ_{t-2}S_tS_{t-2} + S_{t-1}^2 - Q_{t-1}Q_{t-2}S_{t-1}S_{t-2}] - 2[Q_{t-1}S_{t-1} - Q_{t-2}S_{t-2}]\varepsilon_t}{T-1}},$$

$$= \sqrt{-\alpha\bar{S}^2 + \alpha^2\bar{S}^2 + \bar{S}^2 + \sigma_S^2 - \alpha\bar{S}^2 - \delta\bar{S}},$$

$$= \sqrt{(1-\alpha)^2\bar{S}^2 + \sigma_S^2 - \delta\bar{S}} \neq \bar{S}. \qquad (16)$$

As shown above, the Roll estimator does not converge in probability to the average spread. The bias from serial dependence of trade types shows up in (16) as $(1-\alpha)^2 \bar{S}^2$. Trade types are typically positively correlated, so α in general will be positive. By itself, this results in Roll spread estimates that are less than the mean spread. I call this the correlated trade bias. To see how a variable spread affects the estimate, note that

$$\underset{T\to\infty}{Plim}\sqrt{\frac{\sum_{t=1}^{T} S_{t-1}^{2}}{T}} = \sqrt{\bar{S}^2 + \sigma_S^2} \ . \qquad (17)$$

By itself, this bias results in Roll spread estimates that are larger than the mean spread. I call this the variable spreads bias.[3] Finally, I expect $\delta > 0$ as trade type is positively correlated with the succeeding price change. Glosten (1987) points out that the serial covariance of returns is due only to the portion of the spread from factors other than adverse selection. Thus a Roll spread estimate is an estimate of only the spread components other than adverse selection. By itself, this will result in Roll spreads that are less than the mean effective spread. I call this the adverse selection bias. Thus the adverse selection and correlated trades biases will lead to Roll spread estimates that are too low, while the variable spreads bias by itself will lead to Roll spread estimates that are too high. In practice, as I will show, they are nearly offsetting.

To examine the total affect of these biases on Roll estimates, I obtain estimates of α, σ_S^2, and δ for the January 1993 through May 1994 period. To estimate $\alpha = E(Q_t Q_{t-1})$, I use all trade prices for the sample period and determine whether they are buys or sells (their Q's) using their contemporaneous bid and ask quotes. To estimate $\sigma_S^2 = E(S^2) - (E(S))^2$, effective spreads are calculated for each trade using contemporaneous quotes. δ is estimated over January 1993 through May 1994 period as

$$\delta = 2\sum_{t=1}^{T} \frac{\left(\frac{B_t + A_t}{2} - \frac{B_{t-1} + A_{t-1}}{2}\right)(Q_{t-1} - Q_{t-2})}{T}. \qquad (18)$$

Estimates of α, σ_S^2 and δ are used in (16) for each sample stock to generate estimates of the asymptotic biases in the Roll spread[4]. Results are shown in Table 4.

The second column of Table 4 shows the total bias in the Roll spread estimator when all three potential biases are considered together. This is obtained by using estimates of α, σ_S^2 and δ in (16). The total bias is less than 1¢ for nine of the ten large stocks. For medium stocks, the average total bias is about -.6¢, while for small stocks it is about 2¢. Both the small size of the bias for large stocks and the negative bias in the Roll spread estimator for smaller stocks are consistent with what is documented in Table 2.[5]

The total bias is the square root of the sum of the three biases. Thus they cannot be estimated separately. Nevertheless, to provide some perspective on their relative importance, I estimate the correlated trades bias, the variable spreads bias, and the adverse selection bias assuming in each case that the other two biases are absent. These estimates are reported in the third through fifth columns of Table 4.

Note that for all stocks, the correlated trade bias is negative and the variable spreads bias is positive. They tend to offset each other. The adverse selection bias is small relative to either of the others. Finally, notice that the correlated trades bias becomes relatively more important than the variable spreads bias for small stocks. This is again consistent with the observation in Table 2 that Roll spread estimates tend to be too low for small stocks.

As noted earlier, the Roll spread estimator performs poorly when used with daily closing prices. Covariances of returns are often positive, leaving the spread undefined. One reason for this is that the variance of daily returns is large relative to the covariance. That is, the estimator is very noisy. Additional explanations are obtained by considering the three biases examined here. Harris (1989) and Porter (1992) report that closing trades are more likely to occur at the ask price than at the bid. This suggests that the correlated trade bias is particularly severe for closing prices, and will impart a downward bias to Roll spread estimates obtained from closing prices. If the narrowing of spreads near the close that is documented by Christie, Harris and Schultz (1995) is associated with a decline in the variance of the spread, the variable spread bias could be relatively unimportant near the close. Thus while these two biases are almost offsetting during the day, the Roll spread may on net be downward biased when closing prices are used.

G. Estimating Spreads for Different Trade Sizes

In deriving his estimator, Roll assumes the spread is constant. If that assumption is relaxed the Roll spread estimator can be used to simultaneously estimate different trading costs for trades of different sizes. Assume as before that buys and sells are equally likely regardless of whether previous trades were buys or sells. However, now assume that trades of different sizes (or some other characteristic) have different effective spreads, but that all trades of a given size have the same effective spread. In this case a price change will be observed if there is a switch from a buy to a sell, but there may also be a change in price if the trade size changes. Suppose that S_t is the spread for trades of the size that occurred on the tth trade and S_{t-1} is the spread for trades of the size that occurred with the t-1th trade. Q_t takes the value 1 if the trade at t is a buy, and -1 if the trade is a sell. The expected return between trades is μ_t and ε_t is the unexpected change in the true value of the stock. The change in transaction price from trade t-1 to trade t is

$$\Delta P_t = \frac{1}{2}(S_t Q_t - S_{t-1} Q_{t-1}) + \mu + \varepsilon_t \qquad (19)$$

To gain intuition on (19), note that if the spreads for trades t and t-1 are the same, the price change (assuming μ and ε are zero) is the bounce between bid and ask prices. If the spreads for trades t and t-1 are different and both are buys or both are sells (Q's are the same), the change in price will be ½ the difference in the spreads. If the spreads differ and there is a change in the trade types, the price will change by the average of the two spreads. If we assume that μ =0, and that the probability of a buy (sell) is always ½ regardless of the previous trades and for all trade types, the expected product of consecutive price changes can be shown to be

$$E[\Delta P_t \Delta P_{t-1} | S_t, S_{t-1}, S_{t-2}] = -\frac{1}{4} S_{t-1}^2 \qquad (20)$$

Thus, if N^ψ is the number of trades of size ψ and I^ψ_{t-1} equals 1 for trades of size ψ and 0 otherwise, an estimate of the spread for trades of size ψ is given by

$$S^{\psi} = 2\sqrt{\frac{1}{N^{\psi}-1}\sum_{t=2}^{N} -\Delta P_t \Delta P_{t-1} I_{t-1}^{\psi}}. \qquad (21)$$

This says that the Roll estimator can be used to simultaneously estimate different costs for trades of different types. The covariance of the two returns that arise from three trades provide an estimate of the cost of the middle trade. So, for example, to compute the average cost of 1,000 share trades, estimate (21) using all sequences of three prices (two price changes) that have a 1,000 share trade as the second trade. There is no need for consecutive trades of the same type.

To calculate the variance of (ΔP_t ΔP_{t-1}) I assume not only that buys are equally likely to be followed by buys or sells, but also that the sizes of trades are serially independent and independent of trade type.

$$VAR(\Delta P_t \Delta P_{t-1} | I_{t-1}^{\psi}=1) = \frac{\left(\frac{1}{8} S^{\psi^2}\overline{S^2} + \frac{1}{16}(\overline{S^2})^2 + \frac{1}{2}(\overline{S^2})\sigma^2 + \frac{1}{2}S^{\psi^2}\sigma^2 + \sigma^4\right)}{N^{\psi}-1} \qquad (22)$$

The variance of the estimate of S^{ψ} can be obtained through a Taylor series expansion of (22). It is approximately

$$Var(S^{\psi}) = \frac{4}{S^{\psi^2}} VAR(-\Delta P_t \Delta P_{t-1} | I_{t-1}^{\psi}=1) \qquad (23)$$

To examine the effect of trade size on the cost of trading, I separate trades into five size categories; less than 500 shares, 500 to 999 shares, 1,000 shares, 1,001 to 5,000 shares, and more than 5,000 shares. For each stock I calculate the mean effective spread for each trade size category and I also estimate Roll spreads for different trade sizes using (21). This is done separately for each of four periods. As before, the first is from January 1, 1993 up to the first publicity about the Christie-Schultz findings. The second period goes from May 27, 1994 until the U.S. Department of Justice announced their investigation of the Nasdaq market. The third period extends from October 19, 1994 until January 11, 1996 when the NASD's board voted to restructure the Nasdaq market. The final period is from January 11, 1996 through June 30, 1996. Trades of some sizes for some stocks are uncommon. Therefore, trading costs for different size trades are estimated for the entire period, rather than on a day by day basis. Roll estimates are adjusted for the small sample bias from Jensen's inequality in the same manner as before.

Table 5 provides both mean effective spreads and Roll estimates of trading costs for the five trade size categories for each of the sample stocks for the first period, from January 1, 1993 through May 26, 1994. Recall that time stamps of trades and quotes could be matched reliably during this period. Thus the effective spreads in Table 5 provide a benchmark for Roll spread estimates.

During this period, mean effective and mean adjusted Roll estimates are very similar for trades of less than 500 shares and for trades of 500 to 999 shares. The cross-sectional correlation of Roll and effective spread estimators is .97 for trades of 500-999 shares and over .99 for trades of less than 500 shares. For either measure, trades of 500 to 999 shares are much less expensive than trades of less than 500 shares. Thus the adjusted Roll estimator provided in (21) does a good job of estimating differences in effective spreads for trades of different sizes.

For larger trades, there are systematic differences between mean effective spreads and mean adjusted Roll estimates. For large, medium, and small firms, the Roll estimates are less than the effective spreads for trades of 1,000 shares. For trades that are larger than 1,000 shares, Roll spreads are higher than effective spreads. That the Roll spread is larger than the effective spread for orders greater than 1,000 shares is especially interesting. This result appears consistently across stocks and in some cases the differences are quite large. For trades of more than 5,000 shares, the Roll spread exceeds the effective spread by 5.12¢ for Intel and by 6.91¢ for Microsoft.

To see if these differences can be attributed to differences in the biases across trade size I calculate the variable spread bias, correlated trade bias and adverse selection bias as before for each stock, but now for trades of less than 500 shares, 500-999 shares, 1,000 shares, 1,001 - 5,000 shares, and more than 5,000 shares. Table 6 shows the mean of the individual stock biases for large, medium and small stocks for the five trade sizes. The table reveals that the variable spread bias tends to increase with trade size. This is consistent with the findings of Bessembinder and Kaufman (1997) and Huang and Stoll (1996) that the great majority of small Nasdaq trades are executed at the quoted bid or ask while larger trades are more likely to be executed within the spread or outside the spread. Table 6 also shows that the correlated trade bias becomes less negative as trade size increases. In part, the trade type (buy or sell) may be positively correlated for small trades if large orders are broken into several small trades for execution. The changing magnitudes of the variable spread bias and correlated trade bias across trade sizes that are reported in Table 6 are consistent with the observation that Roll spreads usually exceed effective spreads for large trades but not for small trades.

IV. Changes in Nasdaq Trading Costs from January 1993 through June 1996.

A. Trading Costs for All Trades

Table 7 reports mean daily Roll spreads for each sample stock for four periods. The first is from January 1, 1993 through the May 26, 1994, the date of the first publicity about the Christie-Schultz findings. The second period goes from May 27, 1994 through October 19, 1994 when the U.S. Department of Justice announced their investigation of the Nasdaq market. The third period extends from that date until January 11, 1996 when the NASD's board voted to restructure the Nasdaq market. The fourth period runs from January 11, 1996 through June 30, 1996. Trading costs for each period are estimated using the adjusted Roll spread estimator on all trade prices over the period.

Panel A presents results for the ten large stocks. A steady, large decline in trading costs is observed. All ten experience a decline in trading costs between the first and second period. Six of the ten showed further decreases between the second and third periods. Trading costs declined for eight of the ten stocks between the third and fourth period. All of the ten were substantially less expensive to trade in the period after the reorganization of the Nasdaq market was announced than in the first period. For Intel, Microsoft, Cisco Systems, Novell, U.S. Healthcare, and Price-Costco trading costs fell by more than a third.

I calculate t-statistics for differences between Roll spreads in the first period and Roll spreads in subsequent periods using the standard deviation of daily Roll spread estimates from (23) and assuming that the estimates in different periods are independent. Roll spreads that are less than first period Roll spreads at a 1% significance level are denoted by a minus sign (-) in Table 7. For all large stocks, Roll spreads are significantly less in the second, third and fourth periods than in the first.

Panel B provides mean daily adjusted Roll spread estimators for the four subperiods for medium-size firms. Nine of the ten experience a decline in spreads between the first and second periods. Spreads decline for eight of the ten stocks between the second and third periods, and for all ten between the third and fourth periods. The mean daily adjusted Roll spread is lower in the fourth period than the first for each of the ten medium-size stocks. In each case the difference is significant at the 1% level. One notable example is Lone Star Steakhouse (STAR), with a mean Roll spread of $.3334 before May 1994 and a mean of $.1543 after the NASD board approved the Nasdaq restructuring. Over the same time, the adjusted Roll spread declined from $.4069 to $.1583 for Commerce Bancshares (CBSH), from $.2848 to $.1309 for J.B. Hunt (JBHT), and from $.3448 to $.1353 for Giddings and Lewis (GIDL).

Panel C reports mean daily adjusted Roll spreads for the four periods for the sample of small stocks. Small stocks experienced a decline in trading costs over the four periods that is similar to what we observed for large and medium-size firms. Nine of the ten small stocks had a decline in Roll spreads over the four periods, the exception being Citizens Banking Corp (CBCF), which had an increase in spreads from $.7293 in the first period to $.8143 in the last. All the declines are significant at the 1% level. The increase for Citizens Banking Corp is not significant.

The decline in spreads does not appear to be attributable to an increase in firm sizes as a result of the bull market over this period. Four of the ten large stocks, five of the ten medium-size stocks and five of the small stocks had lower market capitalizations at the end of 1995 than at the end of 1993. The rest had larger capitalizations at the end of 1995. All but one of the thirty stocks had smaller Roll spreads in the last period than in the first.

To recapitulate, our results suggest that trading costs, in dollars per share, declined across Nasdaq stocks of all sizes during 1994 through 1996 when the Nasdaq market was under pressure from lawsuits, the U.S Department of Justice, and the Securities Exchange Commission. That costs fell for 29 of 30 stocks implies that the decline in trading costs was very widespread. For many stocks, the reduction in costs was dramatic. The decline in Roll spreads appear to be permanent; we do not observe them returning to previous levels at the end of our sample period.

These results contrast with those of Bessembinder and Kaufman (1997). They examine trading costs for a sample of 300 Nasdaq stocks for 1994 and find neither lower quoted or effective spreads for Nasdaq stocks after May 1994. However, their study differs from this one in important ways. They study only 1994 and their sample includes many Nasdaq stocks that are much smaller than those examined here. I find that the decline in trading costs for the smaller stocks took place primarily after 1994. Also, Bessembinder and Kaufman (1997) report spreads as a percentage of the stock price rather than dollar spreads.

To measure transaction costs as a fraction of the stock price, I divide each day's adjusted Roll spread for each stock by the time-weighted average bid-ask midpoint for that stock. The results, shown in Table 8, indicate that trading costs as a percentage of stock price decline for only eight of the ten large stocks, eight of the ten medium-size stocks and seven of the ten small stocks. For six of the seven stocks with an increase in the percentage spread, the adjusted Roll spread was close to the minimum possible quoted spread of $.125. The increases in percentage spreads for these stocks are driven by a decline in prices, which, unlike dollar spreads, are beyond the control of Nasdaq dealers.

B. Estimates of Trading Costs for Different Size Trades

Table 9 provides a comparison of Roll spreads in the second, third, and fourth periods with Roll spreads prior to the release of the Christie and Schultz (1994) results for trades of less than 500 shares, 500 to 999 shares, 1,000 shares, 1,001 to 5,000 shares and trades of more than 5,000 shares. To save space, I report mean spreads across large stocks, medium-size stocks and small stocks rather than spreads for each security. I conduct a t-test for differences between Roll spreads in the first period and Roll spreads in subsequent periods for each trade size for each stock. The standard error for the differences is calculated using the variance of the Roll estimator given by (23) and assumes that the estimates in different periods are independent. The last three columns of Table 9 provides a count of the number of stocks with Roll spreads in each of the latter period that are less than the 1st period Roll spread.

Table 9 reveals that trading costs fell for trades of all sizes over 1993-1996. Of particular interest is the trading costs for trades of more than 5,000 shares, shown in the last three rows of the table. It has been suggested that if spreads were determined competitively, regulatory pressure to narrow quoted spreads would lead to a decline in the number of dealers and higher trading costs for large trades. Instead, I find that Roll spreads averaged $.2378 for large stocks during the first period, and $.1700 during the fourth period. Over the same time, the costs of trades of over 5,000 shares declined from $.3069 per share to $.2110 per share for medium-size stocks and from $.3451 per share to $.2740 for small stocks.

There is a remarkable consistency in the decline in trading costs both across trade sizes and across stocks. For every large stock, for trades of every size, trading costs in the fourth period are significantly less than trading costs in the first period at the 1% level. As shown in Table 1, small and medium-size stocks have far fewer trades than large stocks. Thus tests for differences in Roll spreads across periods have less power. Despite this, Roll spreads are significantly less in the fourth period than the first for trades of more than 5,000 shares for six medium-size stocks and four small stocks. A larger number of both small and medium-size stocks have significantly lower trading costs in the fourth period than the first for all other trade size categories.

C. Why did Nasdaq Trading Costs Decline?

It is clear that trading costs fell for Nasdaq trades of all sizes over 1993-1996 and that they fell for almost all of the sample stocks. This is consistent with the hypothesis that spreads were not set competitively and declined as a result of regulatory and legal pressure. Other explanations cannot be excluded though.

To see if a decline in the costs of market making could explain the fall in spreads, I use the CRSP tapes to calculate the mean closing bid-ask midpoint, the standard deviation of daily returns (measured using closing bid-ask midpoints), and the mean daily trading volume for each sample stock for each of the four periods. Trading volumes increased for 26 of the 30 sample stocks between the first and fourth periods. If this increase in trading volume is exogenous, it would allow market makers to reduce unwanted inventory more easily and would therefore lead to a reduction in trading costs. The problem though is that it is difficult to determine causality. A decrease in trading costs could also lead to increased volume. I also find that volatility decreased for 21 of the 30 stocks between the first and fourth periods. This could also explain the reduced effective spreads. Lower volatility means less risk from holding inventory for market makers and could leave them willing to buy (sell) at higher (lower) prices. Finally, I find that mean stock prices are lower in the fourth period than the first for 22 of the 30 sample stocks. Numerous studies show that lower stock prices result in lower dollar effective spreads.

To see if the decline in Roll spreads for Nasdaq stocks can be attributed to changes in the stock prices, volatilities and volumes, I calculate percentage changes in all of these variable from the first to the second period, from the second period to the third period, and from the third period to the fourth period. I then run cross-sectional ordinary least squares regressions of the percentage change in the Roll spread between periods on the percentage changes in stock prices, volatility, and daily volume. Results are reported in Table 10.

Coefficients on the change in the standard deviation of returns are positive as expected, but the variable is only significant in explaining changes in Roll spreads between the third and fourth periods. The coefficients on the percentage change in price are positive in all three periods but only significant in the first two. They indicate that a 1% decrease in the mean stock price between the first and second period results in a .2484% decrease in the Roll spread. The coefficients on the change in volume are negative as expected, but the only one that is significant is for the change between the first and second periods.

The important result in Table 10 is that the intercept is negative and highly significant in all three regressions. Even after controlling for changes in volume, volatility, and price, Roll spreads fell by 11.74% between the first and second periods, by 15.38% between the second and third periods, and by 12.39% between the third and fourth periods. Adding the intercept coefficients produces a sum of 39% which is similar to the total decline in trading costs over the period.

D. Was the Decline in Spreads Offset by an Increase in Commissions?

Some authors suggest that if spreads are determined competitively, investors may not be helped by narrower spreads resulting from regulatory pressure because brokers may instead charge higher commissions. If the broker is a market maker and internalizes order flow, he can substitute additional commissions for the foregone spread income. Of course, the brokerage and market making functions are separate, and a market maker may not receive any commission income. However, market makers often pay for order flow. It has been suggested that market makers may eliminate these payments when spreads narrow and that brokerage firms may be forced to raise commissions to compensate for the lost income.

In Table 7, the mean change in Roll spreads was 11.29¢ between the first and fourth periods. This is of course a reduction in the round-trip transactions cost. Thus, ignoring differences in the change in Roll spreads across trade sizes, this implies that commissions on a single trade would have to be higher by $5.60 for 100 share trades, $28 for 500 share trades and $56 for 1,000 share trades for the reduction in Roll spreads to be offset by an increase in commissions.

To compare commissions in the first and fourth periods, I obtain all advertised commissions in the June 28, 1993 and the June 24, 1996 Barrons. The advertisements are usually placed by discount brokerage firms. In some cases they provide information on only their own commissions while in others they explicitly compare their commissions with those of other firms. In some cases the brokers provide specific examples of the costs of trading a given number of shares at a given price. All of these examples are included. In other cases, the broker advertises a price per share. In these cases, commissions are calculated to match every example of a specific trade given in other ads.

Table 11 provides the comparison. For both June 1993 and June 1996 there is a wide range of commissions that are charged by different brokers for each trade. However, it appears that commissions are lower in June 1996 than they were three years before. In 1993, the cheapest commissions were from Lombard, who advertised $15 for any trade. In 1996, the cheapest commissions were from E. Broker, who advertised $12 per trade. In addition, in 1996 there were several brokers, including Pioneer Trading, Washington Discount, Brown and Company, and

R.C. Forbes who advertised fixed rates of $25 to $40 per trade across a wide range of trade sizes.

There are only a handful of instances when the same trade through the same firm shows up in ads in both June 1993 and June 1996. Trades of 100 shares at $10 per share through Schwab were $55 in 1993 and $47 in 1996. Trades of 100 shares at $40 per share through Schwab were $55 in 1993 and $50 in 1996. Schwab trades of 500 shares at $15 were 50¢ more ($1 after rounding) in 1996 than in 1993 while trades of 1,000 shares at $25 cost $155 at both times. For Fidelity customers, trades of 1,000 shares at $25 cost the same amount at both times. Commissions were unchanged or fell slightly while Nasdaq bid-ask spreads were reduced over 1993-1996.

V. Summary and Conclusions

During 1994-1996, the Nasdaq stock market was under intense pressure from regulators and civil lawsuits to lower trading costs. I find that trading costs, as measured by Roll spreads, declined for all trade sizes for almost all sample stocks over 1993 through June 1996. In many cases, costs fell by more than 50 percent. This is consistent with the hypothesis that spreads were not competitively determined on Nasdaq, and that the regulatory and legal pressures on the market had positive benefits for investors. The decline in trading costs remains after adjusting for changes in volume, volatility, and stock prices. Commissions did not increase over this period.

Of course, other factors may well have affected spreads. Instinet trading by institutions has been increasing over the past ten years. This would be expected to lead to lower costs for large trades. In addition, electronic trading by individuals could be expected to reduce brokerage and market making costs and thus spreads and commissions. Finally, increased automation of the industry in general could lead to lower spreads. Analysis of these factors would be interesting for further interpreting the results of this paper and for its own sake. It requires, however, extensive cost data currently not available.

In documenting the decline in spreads, I confront methodological issues that are of concern to any researchers estimating Nasdaq trading costs over 1995-1996. They may also be of concern for the analysis of new equity markets in other countries with less stringent reporting requirements. I find that time stamps do not allow trades to be matched with contemporaneous quotes. Thus effective spreads cannot be estimated reliably. However, the Roll autocovariance spread estimator works well, even with estimation periods of only one day. In addition, I show that the Roll estimator can be used to simultaneously calculate trading costs for trades of different sizes.

References

Barclay, Michael, 1997, "Bid-ask spreads and the evidence of odd-eighth quotes on Nasdaq: An Examination of Exchange Listings", Journal of Financial Economics 45, 35-60.

Benston, George and Robert Wood, 1996, "Spreads and even-eighth quotations on Nasdaq", working paper, Emory University, Atlanta, GA.

Bessembinder, Hendrik, 1999, "Endogenous changes in the minimum tick: An analysis of Nasdaq securities trading near ten dollars", forthcoming, Journal of Financial Intermediation.

Bessembinder, Hendrik, and Herbert Kaufman, 1997, "A comparison of trade execution costs for NYSE and Nasdaq-listed stocks", Journal of Financial and Quantitative Analysis 32, 287-310.

Chan, K.C., William G. Christie and Paul H. Schultz, 1995,"market structure and the intraday pattern of bid-ask spreads for Nasdaq securities, Journal of Business 68, 35-60.

Choi, J. Y., Daniel Salandro, and Kuldeep Shastri, 1988, "On the estimation of bid-ask spreads: Theory and evidence", Journal of Financial and Quantitative Analysis 23, 219-230.

Christie, William, Jeffrey Harris and Paul Schultz, 1994, "Why did Nasdaq market makers stop avoiding odd-eighth quotes", Journal of Finance 19, 1841-1860.

Christie, William and Roger Huang, "Market structures and liquidity: A transactions data study of exchange listings," Journal of Financial Intermediation 3, 300-326.

Christie, William and Paul Schultz, 1994, "Why do Nasdaq market makers avoid odd-eighth quotes?", Journal of Finance 49, 1813-1840.

Doran, Lynn, Kenneth Lehn, and Kuldeep Shastri, 1995, "Do Nasdaq market makers collude? Evidence from 19c3 stocks", working paper, University of Pittsburgh, Pittsburgh, PA.

Glosten, Lawrence, 1987, "Components of the bid-ask spread and the statistical properties of transactions prices", Journal of Finance 42, 1293-1307.

Goldstein, Michael, and Edward Nelling, 1999, "Market making and trading in Nasdaq stocks", Financial Review 34.

Harris, Jeffrey and Paul Schultz, 1997, "The importance of firm quotes and rapid executions: Evidence from the January 1994 SOES Rule Change", Journal of Financial Economics 45, 135-166.

Harris, Lawrence, 1989, “A day-end transaction price anomaly, Journal of Financial and Quantitative Analysis 24, 29-45.

Harris, Lawrence, 1990, “Statistical properties of the Roll serial covariance bid/ask spread estimator”, Journal of Finance 45, 579-590.

Huang, Roger and Hans Stoll, 1996, “Dealer versus auction markets: A paired comparison of execution costs on Nasdaq and the NYSE”, Journal of Financial Economics 41, 313-358.

Porter, David, 1992, “The probability of a trade at the ask: An examination of interday and intraday behavior, Journal of Financial and Quantitative Analysis 27, 209-27.

Porter, David, and Daniel Weaver, 1998, “Post-trade transparency on Nasdaq’s national market system”, Journal of Financial Economics 50, 231-252.

Roll, Richard, 1984, “A simple implicit measure of the effective bid-ask spread in an efficient market”, Journal of Finance 39, 1127-1139.

Table 1. Descriptive statistics for sample stocks. Value refers to the market capitalization of equity on the last date of that month. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period. Mean number of trades is the average number of trades per day for the stock between January 1993 and June 1996.

Panel A. Large Firms

Firm	Ticker	Value 12/92	Value 12/93	Value 12/94	Value 12/95	Mean Daily Number Trades
Intel Corp.	INTC	18,208,400	25,916,000	26,380,368	46,603,104	4,018.1
Microsoft Corp	MSFT	23,819,632	22,897,504	35,513,616	51,772,496	2,614.3
M C I Communications	MCIC	10,421,375	15,283,250	9,996,000	14,238,125	978.2
Tele Communications A	TCOMA	8,125,724	12,175,746	10,678,141	11,360,093	689.0
Oracle Corp	ORCL	4,029,846	8,338,334	12,640,533	18,446,000	1,509.8
Cisco Systems	CSCO	4,771,908	8,152,767	9,187,295	20,623,744	2,297.8
Amgen	AMGN	9,627,671	6,643,593	7,807,352	15,793,750	1,245.5
Novell	NOVL	8,568,098	6,392,058	6,255,899	5,274,723	1,652.6
U.S. Healthcare	USHC	4,318,852	5,618,495	6,598,515	7,139,145	985.4
Price Costco	PCCW	1,675,004	4,189,474	2,804,729	2,977,715	356.2

Table 1 (continued).

Panel B. Medium-size Firms

Firm	Ticker	Value 12/92	Value 12/93	Value 12/94	Value 12/95	Mean Daily Number Trades
Compuware Corp	CPWR	902,332	945,236	1,631,124	784,530	149.3
Lone Star Steakhouse	STAR	576,076	926,970	674,440	1,441,518	175.3
Bob Evans Farms	BOBE	926,396	919,056	864,608	803,909	76.7
Commerce Bancshares	CBSH	886,632	905,884	906,363	1,444,205	17.9
Hon Industries	HONI	761,377	894,824	819,486	706,405	17.0
Cirrus Logic	CRUS	774,340	894,068	675,045	1,247,015	890.1
F H P International	FHPC	653,680	893,870	1,028,352	1,148,322	113.4
J B Hunt Transport	JBHT	886,337	893,195	587,201	648,091	88.7
Staples	SPLS	935,261	889,389	1,472,971	2,557,717	297.3
Giddings and Lewis	GIDL	774,308	882,041	505,837	567,963	109.5

Table 1 (continued).

Panel C. Small Firms

Firm	Ticker	Value 12/92	Value 12/93	Value 12/94	Value 12/95	Mean Daily Number Trades
Peoplesoft	PSFT	292,614	363,063	904,301	2,113,020	217.6
Madison Gas & Electric	MDSN	347,653	361,800	348,400	375,200	11.05
One Valley Bancorp	OVWV	388,636	360,360	480,391	535,438	8.5
Scios Inc	SCIO	320,217	359,878	233,750	155,276	97.5
Citizens Banking Corp	CBCF	252,252	352,900	392,052	425,366	5.5
TBC Corp	TBCC	457,254	351,165	243,109	205,137	32.2
Amtech	AMTC	287,500	349,392	140,592	75,179	121.0
Viewlogic Systems	VIEW	258,803	348,462	308,950	170,030	143.9
Arctic Cat	ACAT	179,513	348,288	427,587	287,248	40.7
Vicor Corp.	VICR	271,724	345,046	375,255	604,240	109.3

Table 2. A comparison of effective spreads, Roll spreads and Roll spreads adjusted for Jensen's inequality for the period from January 1993 through February 1995. The Roll spread is 2 times -1 times the square root of first-order autocovariance of the changes in transaction prices. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1 - 7/8(n-1) where n is the number of trades during the day. Mean effective spreads and adjusted Roll spreads are calculated for each sample stock for each day of the period. The grand means reported in the table are averages of the daily means. Standard deviations reported in the table are standard deviations of the daily means. An observation is missing if there are fewer than three trades during the day or if the Roll spread estimate is negative. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

Panel A. Large firms.

							Regression of Roll Spread on Effective Spread		
Ticker	Grand Mean Effective Spread	Grand Mean Roll Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Intercept Coefficient	Slope Coefficient	R^2
INTC	$.2035	$.2040	$.2041	.0409	.0472	.000 (.000)[a]	-.0163+	1.0834+	.8823
MSFT	.2015	.2057*	.2059*	.0583	.0664	.000 (.000)	-.0174+	1.1081+	.9467
MCIC	.1361	.1384*	.1385*	.0177	.0223	.000 (.000)	-.0039	1.0469	.6879
TCOMA	.1320	.1332*	.1335*	.0152	.0189	.000 (.000)	.0152+	.8964+	.5197
ORCL	.1424	.1406*	.1407*	.0128	.0178	.000 (.000)	-.0046	1.0210	.5386
CSCO	.1982	.1992	.1994	.0547	.0577	.000 (.000)	-.0020	1.0164	.9276
AMGN	.1991	.2010*	.2012*	.0526	.0618	.000 (.000)	-.0202+	1.1119+	.8978
NOVL	.1584	.1586	.1588	.0476	.0533	.000 (.000)	-.0129+	1.0836+	.9386
USHC	.2348	.2364	.2368*	.0267	.0342	.002 (.002)	.0011	1.0038	.6154
PCCW	.1783	.1739*	.1747*	.0744	.0758	.000 (.000)	.0056	.9484+	.8676
Mean	.1784	.1791	.1794	.0401	.0455	.000 (.000)	-.0055	1.0320	.7822

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.

+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.

[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 2 (continued). Panel B. Medium-size firms.

Ticker	Grand Mean Effective Spread	Grand Mean Roll Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Regression of Roll Spread on Effective Spread: Intercept Coefficient	Slope Coefficient	R^2
CPWR	$.3625	$.3098**	$.3159**	.0903	.1085	.004 (.004)[a]	.0829+	.6284+	.2864
STAR	.3100	.2944**	.2975**	.0989	.1076	.000 (.000)	.0194	.8970+	.6800
BOBE	.1799	.1742**	.1777	.0395	.0579	.009 (.009)	.0090	.9383	.4101
CBSH	.4065	.3633**	.4004	.1312	.2319	.084 (.083)	.0136	.9517	.2899
HONI	.4796	.4220**	.4817	.1520	.3146	.187 (.141)	.0708	.8567	.1713
CRUS	.1648	.1539**	.1543**	.0238	.0301	.000 (.000)	-.0016	.9467	.5617
FHPC	.2563	.2455**	.2489**	.0646	.0834	.000 (.000)	.0246	.8572+	.4597
JBHT	.2751	.2602**	.2643**	.0829	.0963	.000 (.000)	.0211	.8840+	.5789
SPLS	.2558	.2445**	.2464**	.0532	.0656	.000 (.000)	.0195	.8869+	.5170
GIDL	.3230	.3087**	.3122**	.0992	.1009	.000 (.000)	.0516+	.8069+	.6303
Mean	.3014	.2777	.2899	.0836	.1197	.028 (.024)	.0311	.8654	.4585

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.

+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.

[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 2 (continued). Panel C. Small firms.

							Regression of Roll Spread on Effective Spread		
Ticker	Grand Mean Effective Spread	Grand Mean Roll Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Intercept Coefficient	Slope Coefficient	R^2
PSFT	$.3448	$.2836**	$.2882**	.0628	.0944	.002 (.002)[a]	.0622	.6555+	.1899
MDSN	.5790	.5069**	.5861	.1749	.3955	.196 (.178)	.0010	1.0105	.1998
OVWV	.6531	.5739**	.7429**	.2629	.6934	.409 (.235)	-.0576	1.2257	.2159
SCIO	.1632	.1536**	.1561**	.0359	.0468	.007 (.007)	.0208+	.8296+	.4042
CBCF	.7276	.6079**	.8074*	.2370	.6130	.503 (.263)	.3028+	.6935+	.0719
TBCC	.1907	.1747**	.1836*	.0549	.0815	.028 (.028)	.0111	.9049	.3710
AMTC	.3490	.3323**	.3357**	.0895	.1017	.000 (.000)	.0158	.9166+	.6506
VIEW	.2824	.2621**	.2661**	.0741	.0936	.002 (.002)	.0205	.8698+	.4747
ACAT	.3965	.3612**	.3874	.1237	.2118	.064 (.055)	.0153	.9384	.3003
VICR	.3649	.3471**	.3524**	.0692	.0980	.004 (.004)	.0022	.9598	.4593
Mean	.4051	.3603	.4106	.1185	.2430	.122 (.077)	.0394	.9004	.3334

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.
+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.
[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 3. A comparison of effective spreads, Roll spreads and Roll spreads adjusted for Jensen's inequality for the period from March 1995 through June 1996. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1 - 7/8(n-1) where n is the number of trades during the day. Mean effective spreads and adjusted Roll spreads are calculated for each sample stock for each day of the period. The grand means reported in the table are averages of the daily means. Standard deviations reported in the table are standard deviations of the daily means. An observation is missing if there are fewer than three trades during the day or if the Roll spread estimate is negative. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period. Panel A. Large firms.

						Regression of Roll Spread on Effective Spread		
Ticker	Grand Mean Effective Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Intercept Coefficient	Slope Coefficient	R^2
INTC	$.1473	$.1332*	.0331	.0260	.000 (.000)[a]	.0837+	.3358+	.1830
MSFT	.1657	.1459*	.0461	.0280	.000 (.000)	.0950+	.3075+	.2560
MCIC	.1150	.1112*	.0111	.0134	.000 (.000)	.0261+	.7395+	.3768
TCOMA	.1185	.1187	.0124	.0151	.000 (.000)	.0245	.7948	.4260
ORCL	.1548	.1405*	.0362	.0167	.000 (.000)	.1017+	.2510+	.2944
CSCO	.1687	.1387*	.0614	.0249	.000 (.000)	.0936+	.2673+	.4353
AMGN	.1598	.1477*	.0268	.0171	.000 (.000)	.1034+	.2771+	.1897
NOVL	.1201	.1113*	.0118	.0129	.000 (.000)	.0241	.7264+	.4392
USHC	.1641	.1520*	.0357	.0398	.000 (.000)	-.0015	.9356	.7054
PCCW	.1223	.1198*	.0194	.0217	.000 (.000)	.0130+	.8729+	.6136
Mean	.1436	.1319	.0294	.0216	.000 (.000)	.0564	.5508	.3919

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.
+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.
[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 3 (continued). Panel B. Medium-size firms.

Ticker	Grand Mean Effective Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Regression of Roll Spread on Effective Spread: Intercept Coefficient	Slope Coefficient	R^2
CPWR	$.2851	$.2610*	.0682	.0664	.000 (.000)[a]	.0718+	.6634+	.4647
STAR	.1775	.1518*	.0319	.0355	.000 (.000)	.0454+	.5992+	.2897
BOBE	.1609	.1577	.0413	.0492	.000 (.000)	.0263+	.8160+	.4693
CBSH	.2855	.2493*	.1101	.1637	.047 (.044)	.0257	.7834+	.2780
HONI	.4631	.4364*	.1423	.2527	.071 (.056)	.0566	.8202	.2132
CRUS	.1708	.1460*	.0403	.0198	.000 (.000)	.1008+	.2644+	.2890
FHPC	.2311	.2073*	.0544	.0634	.000 (.000)	.0407+	.7212+	.3821
JBHT	.1488	.1356*	.0353	.0452	.006 (.003)	.0158	.7959+	.4101
SPLS	.1596	.1530*	.0307	.0312	.000 (.000)	.0263+	.7936+	.6124
GIDL	.1585	.1538*	.0448	.0451	.000 (.000)	.0332+	.7604+	.5722
Mean	.2241	.2052	.0599	.0772	.012 (.010)	.0443	.7018	.3981

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.
+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.
[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 3 (continued). Panel C. Small firms.

						Regression of Roll Spread on Effective Spread		
Ticker	Grand Mean Effective Spread	Grand Mean Adj. Roll Spread	σ (Daily Mean Effective Spread)	σ (Daily Mean Adj. Roll Spread)	Proportion Days Missing	Intercept Coefficient	Slope Coefficient	R^2
PSFT	$.3379	$.2909*	.0697	.0558	.000 (.000)[a]	.1351+	.4612+	.3325
MDSN	.5112	.4778*	.1412	.2896	.172 (.151)	.0010	.9328	.2068
OVWV	.2317	.2287	.0749	.1948	.340 (.281)	-.0508	1.2065	.2153
SCIO	.0946	.0824*	.0264	.0303	.024 (.024)	.0042	.8268+	.5180
CBCF	.7369	.8679*	.2143	.6190	.462 (.210)	.3484	.7050	.0596
TBCC	.1663	.1580	.0487	.0740	.027 (.027)	.0317	.7589	.2495
AMTC	.1754	.1547*	.0469	.0554	.009 (.009)	.0234	.7483+	.4027
VIEW	.1680	.1509*	.0373	.0415	.000 (.000)	.0299+	.7204+	.4194
ACAT	.2271	.2024*	.0770	.0796	.000 (.000)	.0366+	.7300+	.4988
VICR	.3770	.3474*	.1021	.1087	.000 (.000)	.0359	.8265+	.6019
Mean	.3026	.2961	.0839	.1549	.103 (.070)	.0595	.7916	.3505

*T-statistics show that the spread estimate is significantly different from the mean effective spread at the 1% confidence level.
+The coefficient is significantly different from 1 (slopes) or 0 (intercepts) at the 1% confidence level.
[a] The proportion of Roll spreads that are missing because the estimate is undefined is in parentheses.

Table 4. Estimates of biases in the Roll spread estimator. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. The Roll estimator assumes that successive trade types (buys or sells) are independent while buys (sells) are more likely to be followed by buys (sells). This is the correlated trade bias. It also assumes that spreads are constant when they are in fact variable. This is the variable spreads bias. Finally, the Roll spread estimator assumes that changes in stock values are independent of whether the previous trade was a buy or sell. I classify all trades from January 1993 through May 1994 as buys (Q =1), sells (Q=-1) or indeterminate (Q=0) depending on whether the trade price is greater than less than or equal to the contemporaneous bid-ask midpoint. With $\alpha=E(Q_t Q_{t-1})$, S as the effective spread, σ_S^2 as the variance of the effective spread and δ as twice the price change following a shift of the trades from the bid (ask) to the ask (bid), the total bias in the Roll spread estimator is

$$\sqrt{(1-\alpha)^2\overline{S}^2 + \sigma_s^2 - \delta\overline{S}} - \overline{S}$$

I calculate the total bias for each stock using all trades from January 1993 through May 1994. The correlated trades bias is approximated by assuming σ_S^2 and δ are zero. The variable spreads bias is approximated by assuming that α and δ are zero. The adverse selection bias is approximated by assuming α and σ_S^2 are zero. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

Panel A. Large Stocks

	Total	Correlated Trades Bias	Variable Spreads Bias	Adverse Selection Bias
INTC	-.00381	-.05443	.04057	.00002
MSFT	.00399	-.06000	.05110	.00001
MCIC	-.00230	-.03066	.02322	-.00000
TCOMA	-.00696	-.02880	.01785	-.00001
ORCL	-.00382	-.04090	.02880	-.00004
CSCO	-.00696	-.02880	.01785	-.00001
AMGN	-.00562	-.06016	.04310	-.00001
NOVL	.00169	-.03994	.03389	-.00000
USHC	.00219	-.06194	.05085	-.00002
PCCW	.01417	-.03891	.04411	-.00007
Mean	-.00074	-.04445	.03513	-.00001

Table 4 (continued) Panel B. Medium Stocks

	Total	Correlated Trades Bias	Variable Spreads Bias	Adverse Selection Bias
CPWR	-.03596	-.12991	.06831	-.00050
STAR	.00883	-.08095	.07213	-.00047
BOBE	.00179	-.03161	.02849	-.00014
CBSH	-.00715	-.08398	.06443	-.00096
HONI	-.01566	-.11009	.07589	-.00079
CRUS	-.00542	-.05017	.03435	-.00016
FHPC	.00946	-.06988	.06303	-.00030
JBHT	-.00634	-.07002	.05112	-.00019
SPLS	-.00402	-.07772	.05647	-.00015
GIDL	-.00531	-.07892	.05978	-.00016
Mean	-.00598	-.07833	.05740	-.00038

Panel C. Small Stocks

	Total	Correlated Trades Bias	Variable Spreads Bias	Adverse Selection Bias
PSFT	-.03394	-.12099	.06282	-.00083
MDSN	-.03117	-.09715	.05741	-.00122
OVWV	-.06653	-.20040	.10268	-.00124
SCIO	.00228	-.03024	.02775	-.00013
CBCF	-.04346	-.17047	.10172	-.00094
TBCC	-.00045	-.04032	.03296	-.00024
AMTC	.00263	-.08183	.06932	-.00043
VIEW	-.00908	-.07396	.05154	-.00031
ACAT	-.01266	-.09699	.06866	-.00076
VICR	-.01138	-.07297	.05101	-.00038
Mean	-.02038	-.09853	.06259	-.00965

Table 5. Average effective spreads and Roll spreads for trades in different size categories for the period from January 1, 1993 through May 26, 1994. The effective spread for a trade is 2 times the absolute value of the difference between the trade price and the contemporaneous bid-ask midpoint. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1-7/8(n-1) where n is the number of trades during the period. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

Panel A. Large stocks.

	Number of Shares in Trade									
	< 500		500 - 999		1,000		1,001 - 5,000		> 5,000	
	Eff.	Roll	Eff	Roll	Eff	Roll	Eff	Roll	Eff	Roll
INTC	.2663	.2577	.2098	.2120	.2088	.1882	.1786	.2096	.2336	.2848
MSFT	.2899	.2932	.2134	.2005	.2105	.1928	.1891	.2305	.2535	.3226
MCIC	.1678	.1617	.1478	.1519	.1260	.1121	.1200	.1297	.1332	.1597
TCOMA	.1565	.1528	.1445	.1407	.1259	.1147	.1214	.1178	.1302	.1462
ORCL	.1776	.1779	.1502	.1403	.1379	.1175	.1301	.1454	.1586	.2019
CSCO	.2831	.2794	.2196	.2096	.2158	.1802	.1862	.2165	.2289	.2886
AMGN	.2836	.2694	.2241	.2288	.2029	.1963	.1713	.2123	.2262	.2844
NOVL	.2069	.2041	.1769	.1797	.1597	.1500	.1389	.1615	.1662	.2070
USHC	.3027	.3004	.2309	.2220	.2193	.1816	.1788	.2184	.2349	.2994
PCCW	.2216	.2283	.1765	.1820	.1654	.1471	.1357	.1576	.1472	.1833
Mean	.2356	.2325	.1894	.1868	.1772	.1581	.1550	.1799	.1913	.2380

Table 5 (continued). Panel B. Medium-size stocks.

	Number of Shares in Trade									
	< 500		500 - 999		1,000		1,001 - 5,000		> 5,000	
	Eff.	Roll	Eff	Roll	Eff	Roll	Eff	Roll	Eff	Roll
CPWR	.4739	.4374	.4354	.2854	.3576	.2729	.3182	.3377	.3274	.3673
STAR	.4212	.4173	.3248	.3197	.2937	.2543	.2541	.2791	.2743	.3136
BOBE	.2135	.2082	.1714	.1763	.1387	.1268	.1426	.1641	.1572	.1857
CBSH	.5213	.4896	.4158	.4495	.3365	.2704	.3223	.3228	.3082	.3239
HONI	.5640	.5408	.4407	.4488	.3742	.2740	.3734	.3519	.3285	.4109
CRUS	.2137	.1987	.1798	.1465	.1579	.1371	.1530	.1799	.1781	.2285
FHPC	.3555	.3441	.2711	.2811	.2562	.1966	.1995	.2293	.2446	.2936
JBHT	.3552	.3089	.2881	.2768	.4285	.2040	.2216	.2674	.2494	.3440
SPLS	.3614	.3559	.2553	.2326	.2420	.1767	.2004	.2328	.2355	.2946
GIDL	.4524	.4178	.3598	.3598	.2958	.2083	.2533	.2947	.2674	.3103
Mean	.3932	.3719	.3142	.2977	.2881	.2121	.2438	.2660	.2571	.3070

Table 5 (continued). Panel C. Small stocks.

	Number of Shares in Trade									
	< 500		500 - 999		1,000		1,001 - 5,000		> 5,000	
	Eff.	Roll	Eff	Roll	Eff	Roll	Eff	Roll	Eff	Roll
PSFT	.4602	.4255	.3622	.2751	.3150	.2331	.3082	.3419	.3177	.3509
MDSN	.6499	.6382	.5479	.5925	.4392	.4142	.4051	.4012	.3333	.3285
OVWV	.8827	.7957	.7610	.7728	.5310	.3656	.5258	.4943	.4547	.4760
SCIO	.2054	.1952	.1865	.1879	.1469	.1486	.1435	.1564	.1650	.2086
CBCF	.8738	.7655	.6970	.6072	.5183	.4615	.4832	.4977	.5745	.5182
TBCC	.2420	.2206	.2163	.2088	.1576	.1357	.1468	.1625	.1578	.1791
AMTC	.4390	.4188	.3694	.3612	.3373	.3021	.3006	.3432	.3046	.3675
VIEW	.3729	.3386	.2987	.2612	.2502	.2044	.2412	.2902	.2715	.3279
ACAT	.5385	.4983	.4296	.4249	.3478	.3014	.3403	.3521	.3056	.3415
VICR	.4149	.3946	.3526	.3437	.2981	.2911	.2752	.3171	.3031	.3763
Mean	.5079	.4691	.4221	.4035	.3341	.2858	.3170	.3357	.3188	.3475

Table 6. Estimates of Biases in the Roll estimator by trade size. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. The Roll estimator assumes that successive trade types (buys or sells) are independent while buys (sells) are more likely to be followed by buys (sells). This is the correlated trade bias. It also assumes that spreads are constant when they are in fact variable. This is the variable spreads bias. Finally, the Roll spread estimator assumes that changes in stock values are independent of whether the previous trade was a buy or sell. I classify all trades from January 1993 through May 1994 as buys (Q =1), sells (Q=-1) or indeterminate (Q=0) depending on whether the trade price is greater than less than or equal to the contemporaneous bid-ask midpoint. With α=E(Q_t Q_{t-1}), S as the effective spread, σ_S^2 as the variance of the effective spread and δ as twice the price change following a shift of the trades from the bid (ask) to the ask (bid), the total bias in the Roll spread estimator is

$$\sqrt{(1-\alpha)^2\overline{S^2} + \sigma_s^2 - \delta\overline{S}} - \overline{S}$$

I calculate the total bias for each stock using all trades from January 1993 through May 1994. The correlated trades bias is approximated by assuming σ_S^2 and δ are zero. The variable spreads bias is approximated by assuming that α and δ are zero. The adverse selection bias is approximated by assuming α and σ_S^2 are zero. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

	Shares	< 500	500 - 999	1,000	1,001 - 5,000	> 5,000
Panel A: Large Stocks	Total of Three Biases	-$.0194	-$.0074	-$.0079	$.0282	$.0347
	Correlated Trade Bias	-$.0483	-$.0573	-$.0577	-$.0295	-$.0139
	Variable Spread Bias	$.0280	$.0375	$.0370	$.0496	$.0455
	Adverse Selection Bias	$.0002	-$.0001	-$.0003	-$.0001	$.0003
Panel B: Medium-size Stocks	Total of Three Biases	-$.0288	-$.0299	-$.0142	$.0374	$.0426
	Correlated Trade Bias	-$.0727	-$.1037	-$.0951	-$.0472	-$.0339
	Variable Spread Bias	$.0360	$.0534	$.0594	$.0728	$.0685
	Adverse Selection Bias	$.0004	-$.0002	-$.0014	-$.0006	$.0002

Table 6 (continued).

	Shares	< 500	500 - 999	1,000	1,001 - 5,000	> 5,000
Panel C: Small Stocks	Total of Three Biases	-$.0530	-$.0339	-$.0076	$.0240	$.0328
	Correlated Trade Bias	-$.1006	-$.1114	-$.0984	-$.0725	-$.0647
	Variable Spread Bias	$.0386	$.0597	$.0716	$.0807	$.0803
	Adverse Selection Bias	$.0002	-$.0003	-$.0027	-$.0010	$.0002

Table 7. Mean daily estimates of Roll spreads after adjustment for Jensen's inequality. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1 - 7/8(n-1) where n is the number of trades during the day. The first period, 1/1/93 through 5/26/94 is before publicity about Christie-Schultz allegations of collusion among Nasdaq market makers. The second period, 5/27/94 to 10/18/94, is the period between publicity about the Christie-Schultz findings and the announcement of the Department of Justice investigation. The third period, from 10/19/94 through 1/10/96 is the period between the announcement of the Department of Justice's investigation of Nasdaq and the NASD board's approval of the plan to restructure the NASD. Roll spreads that are indicated by a t-test to be significantly less than the stock's first period Roll spread are denoted by a minus sign. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

Panel A. Large stocks.

	Mean Daily Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/19/94-1/10/96	1/11/96-6/30/96
INTC	$.2302	$.1851$^-$	$.1338$^-$	$.1244$^-$
MSFT	.2511	.1207$^-$	.1421$^-$	.1387$^-$
MCIC	.1472	.1282$^-$	.1142$^-$	.1070$^-$
TCOMA	.1369	.1307$^-$	.1215$^-$	.1150$^-$
ORCL	.1458	.1338$^-$	.1394$^-$	.1342$^-$
CSCO	.2407	.1241$^-$	.1424$^-$	.1484$^-$
AMGN	.1793	.1217$^-$	.1160$^-$	.1043$^-$
NOVL	.2380	.1278$^-$	.1374$^-$	.1322$^-$
USHC	.2466	.2168$^-$	.1829$^-$	.1222$^-$
PCCW	.2005	.1298$^-$	.1200$^-$	.1209$^-$
Mean	.2016	.1419	.1350	.1247

Table 7. Panel B. Medium-size stocks.

	Mean Daily Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/194-1/10/96	1/11/96-6/30/96
CPWR	$.3414	$.2886^{-}	$.2578^{-}	$.2570^{-}
STAR	.3334	.2664^{-}	.1627^{-}	.1543^{-}
BOBE	.1816	.1612^{-}	.1667^{-}	.1508^{-}
CBSH	.4069	.3879	.3124^{-}	.1583^{-}
HONI	.4611	.5174	.4457	.3945
CRUS	.1629	.1358^{-}	.1485^{-}	.1357^{-}
FHPC	.2606	.2363^{-}	.2183^{-}	.1852^{-}
JBHT	.2848	.2707	.1493^{-}	.1309^{-}
SPLS	.2621	.2109^{-}	.1799^{-}	.1374^{-}
GIDL	.3451	.2795^{-}	.1800^{-}	.1353^{-}
Mean	.3099	.2755	.2221	.1839

Panel C. Small stocks

	Mean Daily Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/19/94-1/10/96	1/11/96-6/30/96
PSFT	$.2972	$.2936	$.2893	$.2605^{-}
MDSN	.6246	.4404^{-}	.4393^{-}	.5150^{-}
OVWV	.7676	.7030	.2638^{-}	.2141^{-}
SCIO	.1655	.1407^{-}	.0999^{-}	.0794^{-}
CBCF	.7293	.7054	.7920	.8143
TBCC	.1904	.1660^{-}	.1645^{-}	.1496^{-}
AMTC	.3653	.3382^{-}	.1722^{-}	.1566^{-}
VIEW	.2805	.2578^{-}	.1754^{-}	.1387^{-}
ACAT	.4317	.3419^{-}	.2305^{-}	.1701^{-}
VICR	.3629^{-}	.3355	.3606	.2989^{-}
Mean	.4215	.3723	.2988	.2797

$^{-}$ Roll spread is significantly less than the first period at the 1% level (two-tailed t-test).
$^{+}$ Roll spread is significantly more than the first period at the 1% level (two-tailed t-test).

Table 8. Mean daily estimates of Roll spreads after adjustment for Jensen's inequality as a percentage of the stock price. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1 - 7/8(n-1) where n is the number of trades during the day. To express the spread as a percentage of the stock price each day, the adjusted Roll spread is divided by the time-weighted mean bid-ask midpoint for the day. The first period, 1/1/93 through 5/26/94 is before publicity about Christie-Schultz allegations of collusion among Nasdaq market makers. The second period, 5/27/94 to 10/18/94, is the period between publicity about the Christie-Schultz findings and the announcement of the Department of Justice investigation. The third period, from 10/19/94 through 1/10/96 is the period between the announcement of the Department of Justice's investigation of Nasdaq and the NASD board's approval of the plan to restructure the NASD. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

Panel A. Large stocks.

	Mean Daily Percentage Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/19/94-1/10/96	1/11/96-6/30/96
INTC	0.32%	0.30%$^-$	0.19%$^-$	0.20%$^-$
MSFT	0.30	0.22$^-$	0.18$^-$	0.13$^-$
MCIC	0.47	0.55$^+$	0.53$^+$	0.38$^-$
TCOMA	0.58	0.60	0.59	0.59
ORCL	0.39	0.34$^-$	0.35$^-$	0.32$^-$
CSCO	0.59	0.26$^-$	0.25$^-$	0.26$^-$
AMGN	0.74	0.77	0.64$^-$	0.78$^+$
NOVL	0.45	0.54$^+$	0.29$^-$	0.23$^-$
USHC	0.51	0.53	0.49	0.25$^-$
PCCW	0.77	0.87$^+$	0.80	0.67$^-$
Mean	0.51	0.50	0.43	0.38

Table 8 Panel B. Medium-size stocks.

	Mean Daily Percentage Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/19/94-1/10/96	1/11/96-6/30/96
CPWR	1.20%	0.69%$^{-}$	0.95%$^{-}$	1.01%$^{-}$
STAR	1.25	1.25	0.55^{-}	0.41^{-}
BOBE	0.94	0.77^{-}	0.85^{-}	0.96
CBSH	1.25	1.25	0.98^{-}	0.44^{-}
HONI	1.72	1.97	1.65	1.67
CRUS	0.59	0.46^{-}	0.42^{-}	0.69^{+}
FHPC	1.09	0.93^{-}	0.87^{-}	0.62^{-}
JBHT	1.29	1.51^{+}	0.90^{-}	0.68^{-}
SPLS	0.86	0.74^{-}	0.71^{-}	0.63^{-}
GIDL	1.40	1.50	1.10^{-}	0.79^{-}
Mean	1.16	1.11	0.90	0.79

Table 8 Panel C. Small stocks.

	Mean Daily Percentage Adjusted Roll Spread			
Stock	1/1/93 - 5/26/94	5/27/94-10/18/94	10/19/94-1/10/96	1/11/96-6/30/96
PSFT	0.93%	0.77%$^{-}$	0.55%$^{-}$	0.48%$^{-}$
MDSN	1.91	1.39^{-}	1.40^{-}	1.92
OVWV	2.96	2.69	0.93^{-}	0.69^{-}
SCIO	2.23	2.07	1.88^{-}	1.51^{-}
CBCF	2.95	3.12	3.10	2.91
TBCC	1.40	1.57	1.77^{+}	1.99^{+}
AMTC	1.41	2.94^{+}	2.33^{+}	2.27^{+}
VIEW	1.36	1.47	1.40	1.11^{-}
ACAT	1.92	1.35^{-}	1.60^{-}	1.65^{-}
VICR	1.93	1.42^{-}	1.28^{-}	1.79
Mean	1.90	1.88	1.62	1.63

$^{-}$ Percent Roll spread is significantly less than the first period at the 1% level (two-tailed t-test).
$^{+}$ Percent Roll spread is significantly more than the first period at the 1% level (two-tailed t-test).

Table 9. Roll spreads for trades of different sizes. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. The first period is from January 1, 1993 through May 26, 1994. The second period is from May 27, 1994 through October 18, 1994, the third period is from October 19, 1994 up to January 11, 1996, and the fourth period is from January 11, 1996 through June 30, 1996. To adjust for small-sample bias from Jensen's inequality, Roll spreads are divided by 1-7/8(n-1) where n is the number of trades during the period. A t-test is used to compare Roll spreads in latter periods with Roll spreads during the first period. The large firms are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size firms rank 101st through 110th in market capitalization at the end of 1993. The small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period.

	Cross-sectional Mean Roll Spread				Roll Spreads Significantly Less (More) than 1st Period at 1% Level		
Firm Size	1st Period	2nd Period	3rd Period	4th Period	2nd Period	3rd Period	4th Period
			< 500 Shares				
Large	.2325	.1709	.1568	.1439	9 (1)	10 (0)	10 (0)
Medium	.3718	.3479	.2663	.2167	4 (0)	9 (0)	10 (0)
Small	.4688	.4118	.3291	.3145	5 (0)	8 (1)	9 (0)
			500 - 999 Shares				
Large	.1868	.1231	.1312	.1268	10 (0)	10 (0)	10 (0)
Medium	.2976	.2297	.2109	.1911	6 (0)	7 (0)	8 (0)
Small	.4028	.3284	.2771	.2564	5 (0)	8 (1)	7 (0)
			1,000 Shares				
Large	.1581	.1171	.1134	.0966	8 (0)	9 (0)	10 (0)
Medium	.2121	.1958	.1635	.1477	1 (0)	7 (0)	8 (0)
Small	.2853	.2695	.2122	.2001	1 (0)	4 (1)	5 (0)
			1,001 - 5,000 Shares				
Large	.1799	.1238	.1306	.1254	10 (0)	10 (0)	10 (0)
Medium	.2659	.2364	.1999	.1870	5 (0)	6 (0)	8 (0)
Small	.3353	.3092	.2778	.2427	1 (0)	5 (1)	7 (0)
			> 5,000 Shares				
Large	.2378	.1712	.1789	.1700	9 (0)	10 (0)	10 (0)
Medium	.3069	.2561	.2331	.2110	2 (0)	6 (1)	6 (0)
Small	.3451	.2959	.2937	.2740	0 (0)	3 (1)	4 (0)

Table 10. Cross-sectional regressions of percentage changes in Roll spreads for different periods on the percentage change in the standard deviation of returns, the percentage change in the mean closing bid-ask midpoint, and the percentage change in volume. The Roll spread is 2 times the square root of -1 times the first-order autocovariance of the changes in transaction prices. The first period is from January 1, 1993 through May 26, 1994. The second period is from May 27, 1994 through October 18, 1994 and is the time between the release of the Christie and Schultz (1994) findings and the U.S. Department of Justice's announcement that they were investigating pricing practices on Nasdaq. The third period is from October 19, 1994 up to January 11, 1996, when the NASD's board voted to restructure the Nasdaq market. The fourth period is from January 11, 1996 through June 30, 1996. T-statistics in parentheses are based on heteroskedasticity-consistent standard errors.

Dependent Variable	Intercept	% σ Change	% Price Change	% Volume Change	Adjusted R^2
% Change in Roll Spreads 1st to 2nd Period	-.1174 (-2.95)	.0214 (0.19)	.2484 (2.42)	-.1641 (-2.38)	.248
% Change in Roll Spreads 2nd to3rd Period	-.1538 (-3.63)	.0904 (0.74)	.3147 (2.78)	-.0266 (-0.23)	.170
% Change in Roll Spreads 3rd to 4th Period	-.1239 (-4.74)	.0418 (2.37)	.0013 (0.01)	.0064 (0.11)	.107

Table 11. Advertised commissions for assorted trades from Barrons June 28, 1993 and June 24, 1996. All commissions and all competitor commissions from all advertisements are included. Brokerage firms are referred to by superscript as follows. A: American Express, AC: Accutrade, AP: Andrew Peel, BR: Brown and Co., E: E Schwab, EB: E Broker, ET: E Trade, F: Fidelity, FB: R J Forbes, FS: Fidelity Spartan, F+: Fidelity Plus, J: Jack White, K: Kennedy Cabot, L: Lombard, M: Merrill Lynch, N: National Discount, O: Olde, P: Pioneer Trading, PC: PCFN Co., Q: Quick and Reilly, S: Schwab, SB: Smith Barney, S1: Schwab One, W: Waterhouse, WD: Washington Discount.

Trade Size	Price	1993 Commissions: Cost for one trade in dollars.	1996 Commissions: Cost for one trade in dollars.
100	$10	15[L], 48[AC], 54[F] ,55[S]	12[EB] ,25[P,WD], 29[BR],35[FB],38[Q],39[E],47[S],50[M]
100	$25	15[L], 30[K], 48[AC], 54[F] ,55[S], 78[M]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
100	$40	15[L], 36[J], 48[AC] ,55[S]	12[EB] ,20[ET],25[P,WD],29[BR],35[FB],39[E],40[PC],50[S]
150	$30	15[L], 48[AC]	12[EB] ,25[P,WD],29[BR],35[FB],39[E],49[A],82[F+],83[S1]
200	$25	15[L], 30[K], 48[AC], 89[F], 89[S],129[M]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
200	$40	15[L], 48[AC]	12[EB] ,25[P,WD],29[BR],35[FB],39[E],49[A],103[F+,S1]
300	$15	15[L], 48[AC]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
300	$30	15[L], 30[K], 42[J], 48[AC],106[F,S],204[M]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
500	$15	15[L], 45[B], 48[AC],61[W],101[F,S]	12[EB] ,25[P,WD],29[BR],35[FB],39[E],78[Q],101[F],102[S],205[M],213[SB]
500	$40	15[L], 45[B], 48[AC],98[W],129[F],144[S]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
1,000	$20	15[L], 48[AC]	12[EB] ,25[P,WD],29[BR],35[FB],39[E],109[Q],144[F,S],373[M],434[SB]
1,000	$25	15[L], 48[AC],84[FS],155[S],428[M]	12[EB] ,25[N,P,WD],29[BR],35[FB],39[E],69[E],119[Q],125[O,W],155[S]
1,000	$30	15[L], 45[B], 48[AC,],63[J],139[W],151[F],166[S]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
1,000	$31	15[L], 48[AC],50[K],165[F],168[S],488[M]	12[EB] ,25[P,WD],29[BR],35[FB],39[E]
2,000	$25	15[L], 45[B], 60[AC,]191[W],210[F,S]	12[EB] ,25[P,WD],29[BR],35[FB],99[E]
2,000	$35	15[L], 60[AC], 90[k], 270[F],271[S],1021[M]	12[EB] ,25[P,WD],29[BR],35[FB],99[E]
5,000	$10	15[L], 150[AC,AP]	12[EB] ,25[N,P],35[FB],180[Q],250[W],290[S],305[O]
5,000	$20	15[L], 150[AC]	12[EB] ,20[ET,PC],25[P] ,35[FB],159[E],239[S]
5,000	$60	15[L],100[K],150[AC,AP],485[F,S],2252[M]	12[EB] ,25[P],35[FB],159[E]
5,000	$100	15[L], 50[B],150[AC,AP],641[F],705[S],803[W]	12[EB] ,25[P] ,35[FB],159[E]
10,000	$8	15[L], 150[AP], 300[AC]	12[EB] ,25[N,P] ,35[FB],330[Q],500[W],540[S],555[O]
20,000	$5	15[L], 150[AP], 600[AC]	12[EB] ,25[N,P] ,35[FB],527[O],630[Q],1000[W],1040[S]

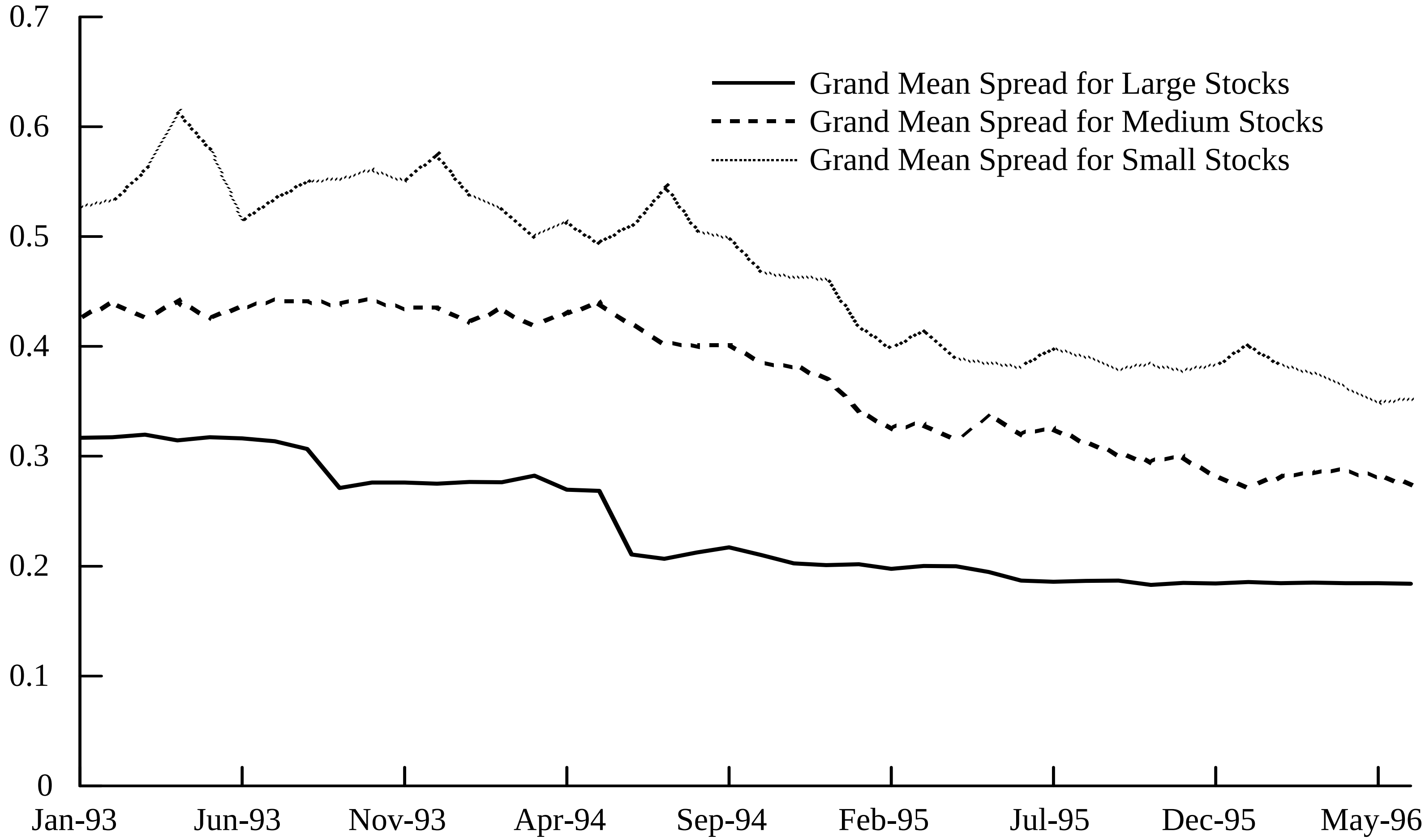

Figure 1. Mean quoted spreads for ten large, ten medium-size and ten small Nasdaq stocks for January 1993 through June 1996. The ten large stocks are the first through tenth largest market capitalization Nasdaq stocks at the end of 1993. The medium-size stocks rank 101st through 110th in market capitalization at the end of 1993. The ten small stocks are the ten from the 301st to 314th in market capitalization at the end of 1993 that were on Nasdaq for the entire January 1993 through June 1996 sample period. Trades at prices above the bid-ask midpoint are categorized as buys (Q=1) while trades at prices below the midpoint are sells (Q=-1) and midpoint trades are undefined. Means are calculated monthly for each stock. A grand mean is then calculated for each size category.

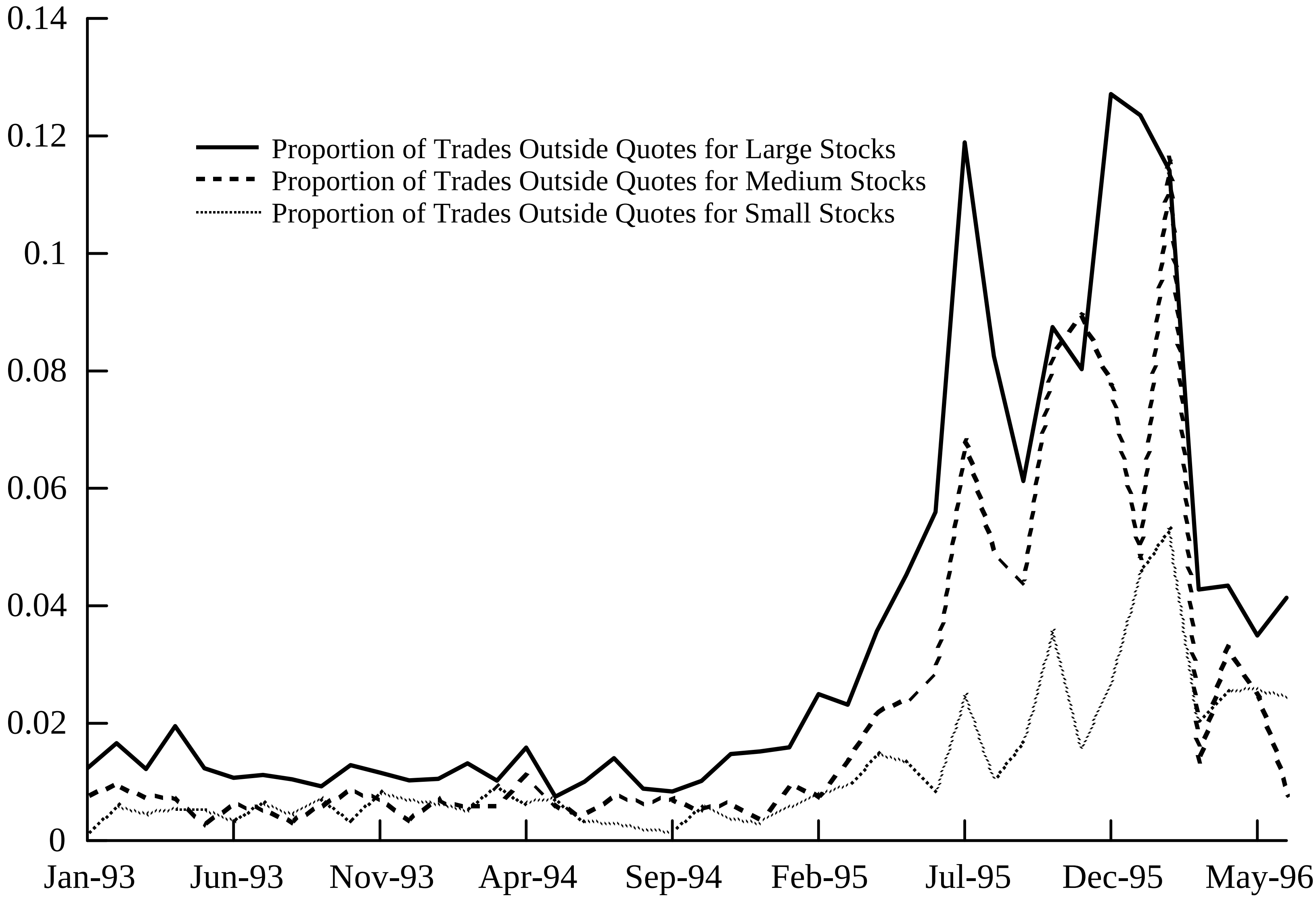

Figure 2. The proportion of trades of 200 shares or less that are outside the contemporaneous inside quotes each month.

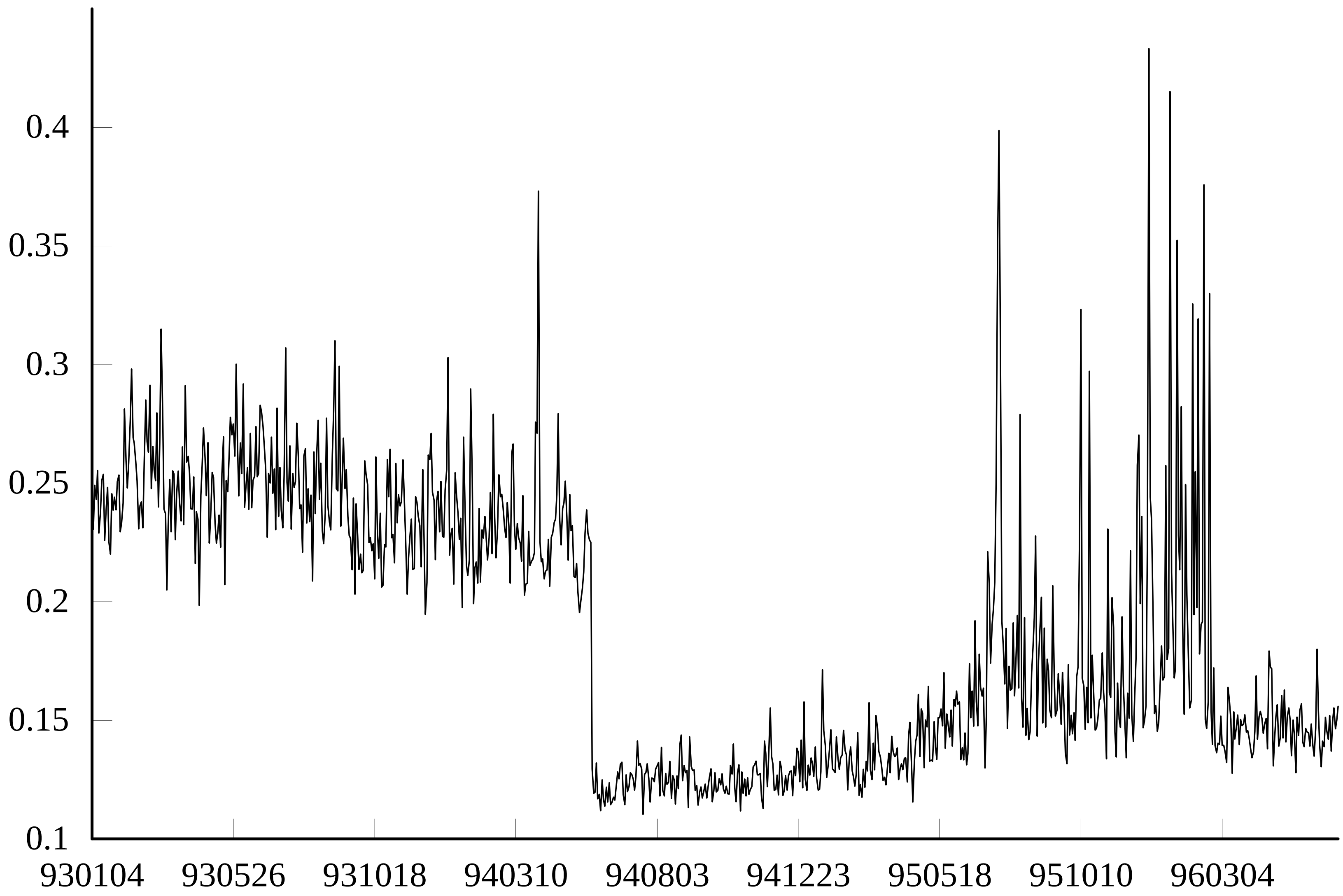

Figure 3a. Microsoft effective spreads calculated daily by matching all trades not reported late with quotes that time-stamps indicate to be contemporaneous.

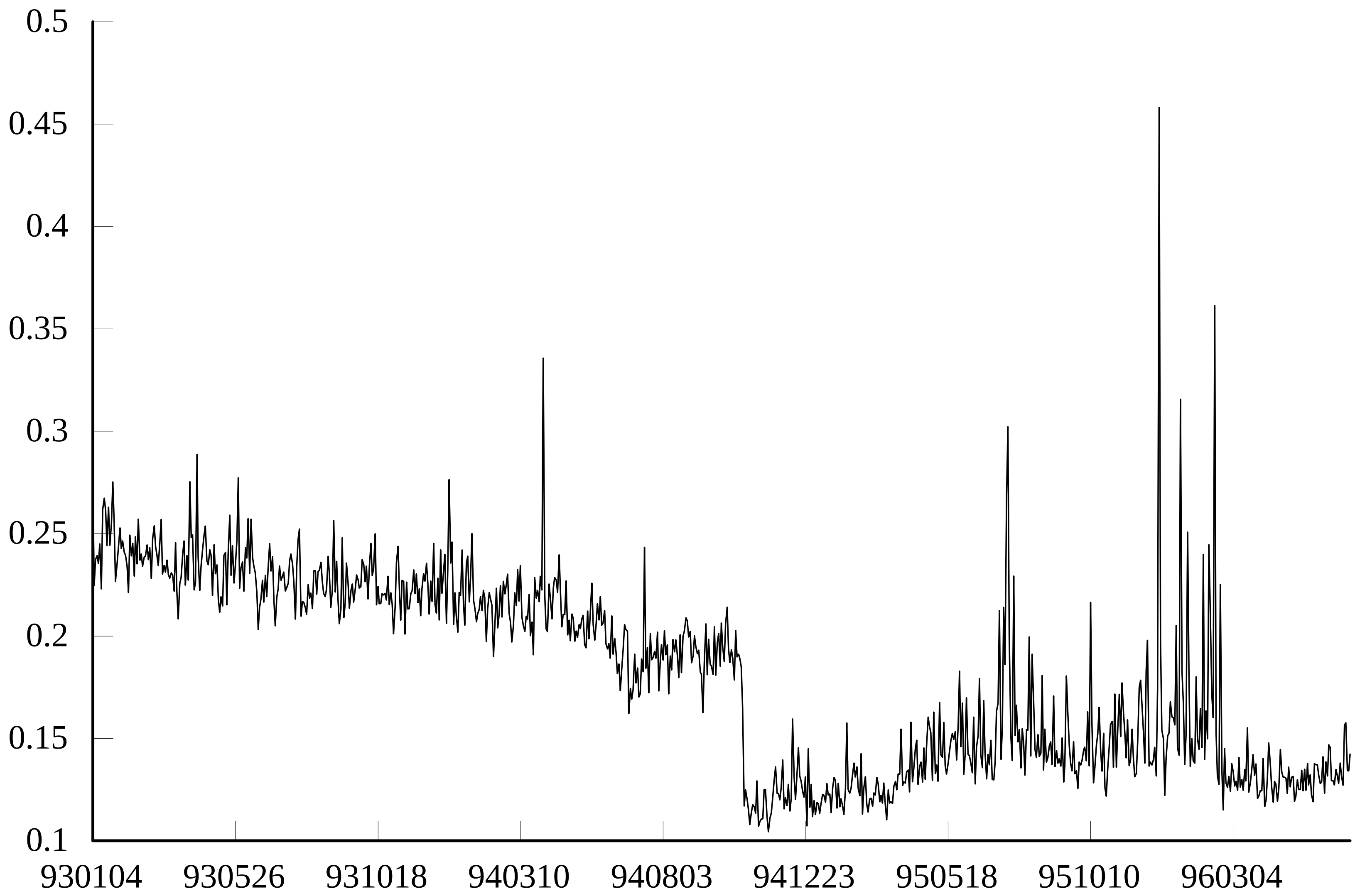

Figure 3b. Intel effective spreads estimated daily by matching all trades not reported late with quotes that time stamps indicate to be contemporaenous.

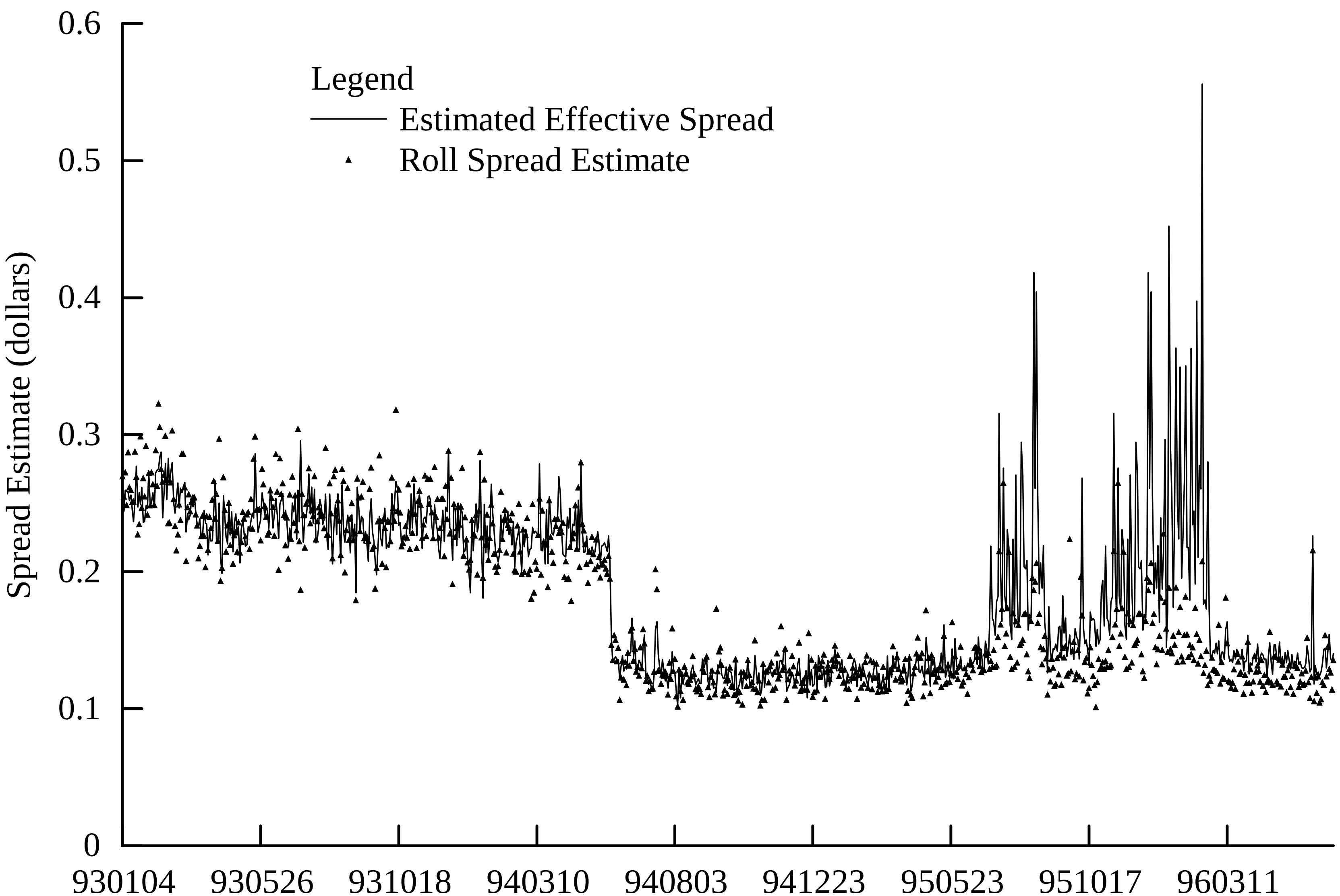

Figure 4. Effective Spreads and Roll Spread Estimates for Cisco Systems

1. See Harris (1990) for a rigorous examination of the small sample properties of the Roll estimator.

2. This is discussed in Christie, Harris and Schultz (1994).

3. I am grateful to Larry Glosten for suggesting that I examine this bias.

4. There are, of course, other potential biases that are not considered here. These include dependence of the trade type on previous increases in the true price and serial correlation of the effective spread. The assumption that the trade indicator Q is Markovian is a basic assumption behind the Roll estimator that may also present problems.

5.Some caution is needed in comparing Table 2 and Table 4. In Table 2, I am interested in how well the Roll spread works when it is estimated daily. Thus the estimates reported there are means of daily estimates. In Table 4 I am estimating large sample properties of the estimator and use all trades over the entire period to produce one estimate of the biases.