Tick Size, Order Handling Rules, and Trading Costs

Kee H. Chung*
State University of New York (SUNY) at Buffalo, Buffalo, NY 14260, U.S.A.

Chairat Chuwonganant
Indiana University-Purdue University at Fort Wayne, Fort Wayne, IN 46805, U.S.A.

Current Version: July 2002

Key words: Spreads; Depths; Price priority; Time priority; Minimum price variation
JEL classification: G14

The authors thank Bidisha Chakrabarty, William Christie, Bob Hagerman, Thomas McInish, Robert Wood, and session participants at the 2001 FMA conference for valuable comments and helpful discussions. The authors are solely responsible for the contents of the paper.

*Corresponding Address: Kee H. Chung, The M&T Chair in Banking and Finance, School of Management, Department of Finance and Managerial Economics, State University of New York (SUNY) at Buffalo, Buffalo, NY 14260. (e-mail) keechung@acsu.buffalo.edu. (phone) 716-645-3262 (fax) 716-645-2131

Tick Size, Order Handling Rules, and Trading Costs

Abstract

In this article, we show that the effect of the tick-size change on Nasdaq spreads depends critically on the order handling rules (OHR). Our empirical results show that the tick-size reduction has no impact on the spread of Nasdaq issues that were not subject to the new OHR. In contrast, the tick-size reduction has a significant effect on the spread of Nasdaq issues that were subject to the OHR. These results indicate that smaller tick sizes are valuable in reducing market friction (Stoll, 2000) *only if* market makers compete on price with public traders for order flow. We find that the tick-size change has no impact on the quoted depth of Nasdaq issues.

1. Introduction

Tick size and order handling rules are two important protocols of securities markets that affect trading costs and market quality. Tick size affects market quality because it limits the prices that traders can quote and thus restricts price competition. Order handling rules affect market quality because they determine the nature and degree of competition among market participants in the price discovery process. In this study we provide further evidence on how tick size and order handling rules affect execution costs on Nasdaq.

On June 2, 1997, the minimum price variation (i.e., tick size) on Nasdaq was reduced from $1/8 to $1/16 for stocks selling at prices greater than or equal to $10. In addition, the Securities and Exchange Commission (SEC) enacted major changes in the order handling rules (OHR) on Nasdaq from January 20, 1997 through October 13, 1997. The new rules allow greater competition between liquidity providers (dealers and public traders) in the quote setting process. The close proximity of these two events provides an excellent opportunity to analyze the complementary nature of their effects on market quality.

Although prior studies (see, e.g., Barclay et al., 1999 and Bessembinder, 2000) examined the effects of changes in the OHR or tick size on Nasdaq spreads, whether these effects are interdependent has not been well understood. In this article, we show that the effect of the tick-size change on Nasdaq spreads depends critically on the OHR. Specifically, we show that change in tick size exerted a significant impact on Nasdaq spreads only after the implementation of the new OHR. This finding is important because it underscores the fact that smaller tick sizes are valuable in reducing market friction (Stoll, 2000) *only if* market makers compete on price with public traders for order flow.

Ahn, Cao, and Choe (1996) examine the change in liquidity when the Amex reduced the minimum price variation and find that both the spread and depth declined after the tick-size reduction. Bacidore (1997), Porter and Weaver (1997), Ahn, Cao, and Choe (1998), and Griffiths

et al. (1998) examine the impact of the tick-size change on liquidity for stocks listed on the Toronto Stock Exchange (TSE) and show that both the spread and depth declined after the tick-size reduction. Bollen and Whaley (1998) and Goldstein and Kavajecz (2000) find similar results for NYSE-listed stocks.

Harris (1994, 1997) holds that the effect of tick size on execution costs is likely to be significant only in markets with a price-time priority rule. Harris conjectures that the tick-size change will have a significant effect on Nasdaq spreads only if market makers compete with public traders. Although previous studies show that the tick-size change has a significant effect on spreads in hybrid (e.g., NYSE and Amex) or purely order-driven (e.g., TSE) markets, its effect on the spread of Nasdaq issues has not been well documented. In this study, we perform empirical analysis of the effect of the tick-size change on Nasdaq spreads.

Simaan, Weaver, and Whitcomb (1998) analyze the quotation behavior of Nasdaq dealers after the tick-size change. The main focus of their study, however, is whether Nasdaq dealers continue to avoid odd ticks after the tick-size reduction. Bessembinder (2000) shows that quoted and effective spreads on Nasdaq are two to four cents less when stocks trade below $10 per share with a smaller tick size. Bessembinder finds that the largest spread reductions occur for stocks whose market makers avoid odd-eighth quotes. Van Ness, Van Ness, and Pruitt (2000) examine the effect of tick size on volume, volatility, and execution costs for both NYSE and Nasdaq issues.

In a recent study, Weston (2000) analyzes the effect of the new OHR on the execution costs of Nasdaq issues. The study finds that changes in inventory and information costs cannot explain the post-reform decrease in Nasdaq spreads. In addition, the study provides evidence that the rule change led to a significant reduction in the difference between NYSE and Nasdaq spreads. The main thrust of Weston's study was, however, to examine how the new OHR affected competition among liquidity providers on Nasdaq.

In contrast, the present study examines whether the effect of the tick-size change on Nasdaq spreads differs between Nasdaq issues that were subject to the new OHR before and after the introduction of the new tick size. Because the new OHR allow limit order traders on Nasdaq to become direct participants in the quote setting process, the results of the present study shed further light on the role of limit order traders in price discovery.[1]

Our empirical results show that the tick-size reduction led to narrower spreads for both Nasdaq stocks and a control sample of NYSE stocks. When we separate our Nasdaq stocks into two groups according to whether a stock was subject to the new OHR before or after the tick-size change, we find that the tick-size reduction has a significant impact on the spread of Nasdaq issues that were subject to the new OHR before the tick-size change. For the group of Nasdaq issues that were not subject to the OHR at the time of the tick-size change, however, we find no evidence of spread changes. These results support Harris' (1997) conjecture that the reduction in tick size will narrow Nasdaq spreads only if limit order traders and dealers compete on quoted price for order flow. We find that the tick-size reduction has no impact on the quoted depth of Nasdaq stocks, whereas the control sample of NYSE stocks exhibited smaller depths after the tick-size reduction. On the whole, our empirical results suggest that the new OHR and the smaller tick size jointly narrow spreads on Nasdaq without adversely affecting depths.

The paper is organized as follows. In Section 2, we discuss the likely effects of the tick-size change on the spread and depth of Nasdaq stocks. Section 3 explains our data and methodology. Sections 4 and 5 present our empirical findings. Section 6 provides a brief summary and concluding remarks.

[1] See Chung, Van Ness, and Van Ness (1999, 2001) and Kavajecz (1999) for the discussion of the role of limit order traders in the quote setting process.

2. Price-time priority rule, tick size, and execution costs

One of the important protocols of exchange markets is the price-time priority rule. The price priority rule ensures that buyers who are willing to pay the highest price will be the first to buy and sellers who are willing to sell at the lowest price will be the first to sell. The time priority rule assures that the first order placed will be executed first among those orders submitted with the same bid (or ask) price. The price-time priority rule promotes competition among liquidity providers and thereby lowers trading costs.

A reduction in the minimum price variation is likely to decrease execution costs in markets with a price-time priority rule, such as the NYSE.[2] The minimum price variation limits the prices that traders can quote and thus restricts price competition–traders cannot improve the best bid or offer when the spread is equal to the minimum price variation.[3] Because the minimum price variation is less likely to be a binding constraint on absolute spreads when tick size is small, the spread is expected to decrease when there is a reduction in tick size.

Nasdaq does not generally enforce the time priority rule among dealer quotes. The time priority rule is enforced only among dealer quotes for dealers who participate in the Small Order Execution System (SOES). Harris (1997) holds that a smaller tick size will narrow spreads on Nasdaq only if traders compete on price to obtain order flow. Prior to the 1997 Nasdaq OHR changes, only a few dealers competed on price because they did not face competition from public traders. A dealer who improves price does not attract large order flow because all other dealers will match the price for their clients. Brokers route most retail orders to dealers according to

[2] On the NYSE, Rule 2072 requires that the time priority rule be strictly enforced for the first public bid (or offer) at a given price. The NYSE enforces price priority and uses a combination of order size and order placement time to determine priority for limit orders that are tied on price. Price and time priority rules are not enforced, however, across the markets that trade NYSE-listed stocks. For example, limit orders left with Boston, Pacific, or Cincinnati Exchanges do not have time priority over limit orders left with the NYSE. In the present study, we exclude off-NYSE quotes from the study sample.

prearranged preferencing agreements. Hence, for Nasdaq stocks, we expect that a reduction in tick size will have a significant effect on spreads only after the implementation of the new OHR. These considerations lead to the following hypothesis:

Hypothesis 1: A reduction in tick size will narrow the spreads of Nasdaq stocks that are subject to the new OHR before the tick-size change. For Nasdaq stocks that are not subject to the new OHR at the time of the tick-size change, the effect of the tick-size change on spreads is likely to be insignificant.

The minimum price variation is likely to affect quoted depths when the minimum price variation is larger than the spread that dealers would otherwise quote. In this case, the quoted spread (i.e., the minimum price variation) is larger than the desired spread and thus supplying liquidity is profitable. If the market enforces time preference, dealers and other liquidity providers will queue up to offer liquidity and quoted depths will be large. If the market does not enforce time preference, or if trade occurs in several markets that do not coordinate to enforce time preference, the effect of the minimum price variation on quoted depths is likely to be insignificant because dealers may use other means (e.g., payment for order flow and internalization) to obtain order flow.

The minimum price variation may affect quoted depths even if quoted spreads are greater than the minimum price variation on the NYSE. The minimum price variation determines the minimum cost of acquiring order precedence through price priority when time precedence is enforced. Time precedence and a large minimum price variation protect traders who display size by forcing quote matchers to improve price significantly if they wish to acquire precedence. Hence, quote matchers are less likely to front-run if the minimum price variation is large. Traders on the NYSE are therefore more likely to quote large depths when the minimum price variation is

[3] Harris (1994) suggests that the negative correlation between the percentage spread and share price reported in previous studies can be explained by the fact that price level determines the percentage spreads of low-price stocks for which the minimum price variation is a binding constraint on absolute spreads.

large. In contrast, the relation between quoted depths and the minimum price variation is likely to be insignificant for Nasdaq issues because Nasdaq does not enforce time precedence among dealer quotations. These considerations lead to our second hypothesis:

Hypothesis 2: The effect of the tick-size change on depths is likely to be insignificant for Nasdaq stocks.

In the following sections, we present our empirical findings regarding these hypotheses.

3. Data source and sample selection

We obtain the data used in this study from the NYSE's TAQ database. Although the main purpose of this study is to examine the effect of the tick-size change on the spread and depth of Nasdaq stocks, we include a control group of NYSE stocks in our study sample to help ensure that our results are not driven by the attributes of our Nasdaq study sample. We use trade and quote data during 30 trading days before and after the dates on which the minimum price variation changed from \$1/8 to \$1/16 on Nasdaq (June 2, 1997) and the NYSE (June 24, 1997). Since the tick-size reduction on Nasdaq applies only to stocks that have a bid price of \$10 or more, we exclude Nasdaq and NYSE stocks that had a bid price of less than \$10 at least once during the study period. We also restrict our Nasdaq sample to only those with four-letter ticker symbols. This leaves us with a sample of 2,073 Nasdaq stocks and 2,242 NYSE stocks.

To check whether our results are sensitive to different sample selection methods, we obtain a sample of Nasdaq and NYSE stocks with at least 300 trades during the study period. This second sample consists of 1,641 Nasdaq stocks and 2,150 NYSE stocks.

We exclude off-NYSE quotes for our NYSE stocks. In addition, we exclude the following trades and quotes to minimize data errors: (1) quotes if either the bid price or the ask price is non-positive; (2) quotes if either the bid size or the ask size is non-positive; (3) quotes if the bid-ask spread is greater than \$5 or negative; (4) trades and quotes if they are out of time

sequence, involve an error, or involve a correction; (5) quotes associated with trading halts or designated order imbalance; (6) before-the-open and after-the-close trades and quotes; (7) trades if the price or volume is non-positive; (8) trade price, p_t, if $|(p_t - p_{t-1})/p_{t-1}| > 0.10$; and (9) ask quote, a_t, if $|(a_t - a_{t-1})/a_{t-1}| > 0.10$ and bid quote, b_t, if $|(b_t - b_{t-1})/b_{t-1}| > 0.10$.

The effect of the tick-size change on spreads is likely to vary with stock attributes. For example, the spread of low-price stocks is more likely to be affected by the tick-size change than the spread of high-price stocks because the minimum price variation is more likely to be a binding constraint on absolute spreads for low-price stocks. For the same reason, the spread of high-volume stocks is more likely to be affected by the tick-size change than the spread of low-volume stocks. Hence, we obtain the control sample of NYSE stocks that are similar in share price, number of trades, trade size, return volatility, and firm size to our sample of Nasdaq stocks.

We measure share price by the average daily closing price and return volatility by the standard deviation of daily returns during 30 trading days before the tick-size change. We measure trade size by the average dollar transaction size during the same period.[4] We measure firm size by the market value of equity on May 31, 1997.

To obtain the control sample of NYSE stocks, we first calculate the following composite match score (CMS) for each Nasdaq stock against each of 2,242 NYSE stocks in our sample:

$$\text{CMS} = \Sigma[(Y_k^N - Y_k^Y)/\{(Y_k^N + Y_k^Y)/2\}]^2, \quad (1)$$

where Y_k represents one of the five stock attributes, the superscripts, N and Y, refer to Nasdaq and NYSE, respectively, and Σ denotes the summation over $k = 1$ to 5. Then, for each Nasdaq stock, we select the NYSE stock with the lowest score. Once a NYSE stock is matched with a Nasdaq

[4] Nasdaq uses the same volume counting rules as the NYSE. Nonetheless, the reported number of trades on Nasdaq is not directly comparable to that on the NYSE because there are many inter-dealer trades on Nasdaq. Because the recommended adjustment factor for Nasdaq volume that will neutralize the effect of inter-dealer trades is about 30 to 50% (see, e.g., Atkins and Dyl, 1997), we replicate our matching

issue, the NYSE stock is no longer considered for subsequent matches. This procedure results in 518 pairs of Nasdaq and NYSE stocks with similar attributes.[5]

We report descriptive statistics of the variables in Table 1. The average share price of our sample of Nasdaq stocks is $24.98 and the corresponding figure for our control sample is $24.89. The average daily number of transaction and trade size for the Nasdaq sample are 50.66 and $38,946, respectively, and the corresponding figures for the control sample are 48.55 and $40,312. The mean values of the standard deviation of daily returns for our Nasdaq and NYSE stocks are 0.0231 and 0.0215, respectively. The average market values of equity for our Nasdaq and NYSE firms are $656.2 millions and $691.6 millions, respectively. The results of t-test show that the mean values of these stock attributes are not significantly different between our Nasdaq and NYSE study samples.

4. Effects of the tick-size change on spreads

4.1. Tick size and spreads

We use three measures of trading costs in this study: the quoted dollar spread, quoted percentage spread, and effective spread.[6] The quoted dollar spread is the difference between the posted ask and bid prices. The quoted percentage spread is obtained by dividing the quoted dollar spread by the quote midpoint. We calculate the effective spread using the following formula:

$$\text{(2)} \qquad \text{Effective spread}_{it} = 2D_{it}(P_{it} - M_{it}),$$

---

procedure after we multiply NYSE volume by 1.4. The results from the new matching sample, however, do not change our main results in any significant manner.

[5] We find that differences in one or more stock attributes between Nasdaq and NYSE stocks become considerable when the CMS exceeds three. Hence, to ensure the quality of our matching sample, we include only those pairs (518 pairs) with a CMS of less than three in our study sample.

[6] A large number of quote updates for NYSE-listed stocks originate from off the NYSE. As Blume and Goldstein (1997) show, however, quotes that originate from off the NYSE only occasionallybetter NYSE quotes. Hence, we use only NYSE quotes in our study.

where P_{it} is the transaction price for security i at time t, M_{it} is the midpoint of the most recently posted bid and ask quotes for security i, and D_{it} is a binary variable which equals +1 for customer buy orders and -1 for customer sell orders. We estimate D_{it} using the algorithm in Lee and Ready (1991). The effective spread measures the actual execution cost paid by the trader.

Table 2 shows the average time-weighted dollar and percentage spreads and the average trade-weighted effective spread for our Nasdaq stocks and the control sample of NYSE stocks.[7] The dollar, percentage, and effective spreads during the post tick-size change period are all smaller than those during the pre tick-size change period for both Nasdaq stocks and the control sample. On average, Nasdaq stocks experienced a 4.1% decline in the dollar spread whereas NYSE stocks experienced an 8.8% decline. Similarly, Nasdaq stocks experienced an 11.2% decline in the percentage spread whereas the corresponding figure for NYSE stocks is 15.5%.[8] For the effective spread, Nasdaq stocks experienced a 6% decline whereas the control sample experienced a 15.8% decline. When we replicate the above analysis using only those stocks with at least 300 trades during the study period, the results (see panel B) are qualitatively similar.

The above results indicate that the tick-size reduction led to narrower spreads for both NYSE and Nasdaq stocks, although the magnitude of decline for Nasdaq stocks is smaller than the corresponding figure for NYSE stocks.[9] Note that our Nasdaq sample consists of two very

[7] Spreads are equally weighted across stocks.

[8] These figures are smaller than the prediction (30%) made in Harris (1994). The observed discrepancy may be due to the differences in stock attributes between Harris' and our study sample of stocks.

[9] To the extent that spreads are correlated with the attributes of underlying stocks, it is possible that the observed changes in spread may be due to changes in the stock attributes between the two periods, rather than to the change in tick size per se. To measure the effect of the tick-size change on the spread after controlling for concurrent changes in the stock attributes, we estimate the following regression model: $SPREAD^{pre} - SPREAD^{post} = \alpha_0 + \Sigma\alpha_i (X_i^{pre} - X_i^{post}) + \varepsilon$; where SPREAD denotes the spread, superscripts 'pre' and 'post' denote, respectively, the pre and post tick-size change values of the variables, X_i (i = 1 to 5) represents one of the five stock attributes in Table 1, Σ denotes the summation over i = 1 to 5, αs are the regression coefficients, and ε is the error term. We find that the estimates of α_0 are all significantly different from zero and are similar to the observed spread differences between the two periods shown in Table 2. These results suggest that most of the observed decline in spread is due to the change in tick size, not due to any concurrent changes in the stock attributes.

distinct groups of stocks: stocks that were subject to the new OHR before the tick-size change and stocks that were subject to the rules after the tick-size change. In the next section, we perform empirical analysis of whether the observed changes in Nasdaq spreads are driven by only the first group of stocks.

4.2. Order handling rules and the effect of the tick-size change on Nasdaq spreads

The SEC enacted major changes in the OHR on Nasdaq in 1997. The first rule, known as the "Limit Order Display Rule," was phased-in for all Nasdaq National Market System issues from January 20, 1997 to October 13, 1997. The rule requires that limit orders be displayed in the Nasdaq BBO (i.e., best bid and offer) when they are better than quotes posted by market makers. This new rule allows the general public to compete directly with Nasdaq market makers in the quote setting process. The second SEC rule, known as the "Quote Rule," requires market makers to publicly display their most competitive quotes. This rule allows the public access to superior quotes posted by market makers in Electronic Communication Networks (ECNs).[10] Under the new rule, if a dealer places a limit order into Instinet or another ECN, the price and quantity are incorporated in the ECN quote displayed on Nasdaq.[11]

Nasdaq does not have a Central Limit Order Book (CLOB). Limit orders placed with dealers might have to be displayed in the quotes due to the OHR, but these limit orders do not necessarily have time priority over other limit orders at the same price posted with a different

[10] ECNs are proprietary trading systems such as Instinet that are used exclusively by marketmakers and large institutions.

[11] The third SEC rule, known as the "Actual Size Rule," reduces the minimum quote size (depth) of market makers from 1000 shares to 100 shares and thereby allows greater flexibility in their quote decisions. This rule was enacted in the belief that the smaller minimum depth requirement reduces the risks that Nasdaq dealers must take and thereby encourages market makers to maintain competitive quotes. The last feature of the OHR changes involves an amendment in the "Excess Spread Rule (ESR)." Prior to January 20, 1997, the ESR required Nasdaq dealers to maintain their spreads within 125% of the average of the three narrowest spreads for each stock. The amended ESR requires that each dealer's average spread during each month be smaller than 150% of the average of the three narrowest spreads over the month. The new ESR

dealer. Thus, Nasdaq is a market in which the better prices get posted across multiple dealers, but one without a strict time priority. Nevertheless, Nasdaq under the new OHR more closely resembles the system under which NYSE-listed stocks are traded.

Harris (1997) predicts that Nasdaq spreads will narrow with a smaller tick size if public limit orders have sufficient precedence to compete effectively with dealers. Since our Nasdaq sample includes stocks that were subject to the new OHR before the tick-size change as well as after the tick-size change, the observed effect of tick size on Nasdaq spreads may have been driven by those stocks that were subject to the rules before the tick-size change.

To examine whether the impact of tick size on Nasdaq spreads differs depending on whether dealers were subject to competition from public limit orders, we compare the effect of the tick-size change on spreads between Nasdaq stocks that were subject to the new OHR before the tick-size reduction (the OHR stocks hereafter) and Nasdaq stocks that were not subject to the new OHR at the time of the tick-size reduction (the non-OHR stocks hereafter). As our study period covers 30 trading days before and after the event date (June 2, 1997), we select the first group of Nasdaq stocks from the first four batches of 50 stocks that were subject to the new OHR from January 20, February 10, February 24, and April 21, and the second group from those Nasdaq stocks that were subject to the new rules after July 15.[12]

We obtain a control sample of NYSE stocks for the OHR stocks using the same procedure described in Section 3.[13] Likewise, we obtain a control sample of NYSE stocks for the non-OHR stocks.[14]

---

defines compliance on a monthly basis rather than continuously and therefore poses less restriction on dealers' ability to change their spreads. See Barclay etal. (1999) for a detailed description of these rules.

[12] Hence, our study sample excludes 10 batches (April 28, May 5, May 12, May 19, May 27, June 2, June 9, June 23, June 30, and July 7) of 50 stocks that were subject to the new OHR during the 30 days before and after the change in tick size.

[13] We use 83 pairs of Nasdaq and NYSE stocks with a CMS of less than three.

[14] We use 388 pairs of Nasdaq and NYSE stocks with a CMS of less than three.

Table 3 (panel A) shows that the average dollar spreads during the pre and post tick-size change periods are \$0.3209 and \$0.2808, respectively, for the OHR stocks. When we replicate the analysis using the percentage and effective spreads, we also find smaller spreads after the tick-size change. The results of t-test indicate that the observed changes in spreads are all statistically significant. When we limit our study sample to stocks with at least 300 trades, the results are identical to those based on the whole sample.[15]

Overall our empirical results are consistent with Harris' (1997) conjecture that the tick-size reduction will narrow spreads for Nasdaq issues if public limit orders compete with dealer quotes in the quote setting process. Nasdaq dealers are more likely to improve price with a smaller tick size as the Limit Order Display Rule subjects them to competition from limit order traders.[16]

Table 3 shows the effect of the tick size change on spreads for the non-OHR stocks. We find that the tick-size reduction has only marginal and insignificant effects on the dollar, percentage, and effective spreads. Note that in all cases, the observed changes in spreads are not statistically significant. Overall, our empirical result indicates that the smaller tick size did not narrow spreads on Nasdaq prior to the implementation of the new OHR. This result is consistent with the prediction of Harris (1997) that the tick-size reduction is likely to have no effect on the spreads of stocks traded in a dealer market where a dealer faces no competition from public traders.

Panel B of Table 3 shows the results from the control sample of NYSE stocks. The results show that both groups of NYSE stocks experienced a significant reduction in spreads. Because our control sample of NYSE stocks (with similar attributes as the Nasdaq sample)

[15] The results are available from the authors upon request.

[16] The 1997 market reform involves other rule changes and thus the observed effect of the ticksize change on spreads may reflect the effects of other rule changes. Our empirical measures, however, cannot separate out these different effects.

experienced a significant decline in spreads, the lack of a significant change in spreads for the non-OHR stocks is not likely to be due to their attributes.

Although our results suggest that the tick-size change on Nasdaq affected only those stocks subject to the new OHR, it is possible that the results are due to the difference in the pre tick-size change spread between the OHR stocks and the non-OHR stocks. For example, if the old tick size were a binding constraint for the OHR stocks but not for the non-OHR stocks, the smaller tick size would lead to narrower spreads only for the OHR stocks. To examine this issue, we perform a matching sample comparison of spreads between the two groups of Nasdaq stocks.

To obtain matching samples of Nasdaq stocks, we calculate the composite match score (CMS) for each Nasdaq stock that was subject to the new OHR before the tick-size change against each of 1,525 Nasdaq issues that were subject to the new OHR after the tick-size change. Then, for each stock from the first group, we select the stock from the second group that has the lowest score. This procedure results in 77 pairs of Nasdaq stocks.[17]

We show the results in Table 4. Note that the reduction in tick size has a significant effect on all three measures of execution cost for the OHR stocks. In contrast, we find no such effect for the non-OHR stocks. We obtain similar results (not reported) from stocks with at least 300 trades during the study period. On the whole, these results suggest that the different effects of tick size on spreads shown in Table 3 may not be attributed to the difference in spreads between the two Nasdaq samples before the tick-size change.

Table 4 shows the proportions of even-eighth quotes among eighths during the pre and post tick-size change periods for both groups of Nasdaq stocks. The results show that the average proportion of even-eighth quotes for the non-OHR stocks is significantly higher than the corresponding figure for the OHR stocks during both periods. (The t-values for testing the

[17] To ensure the quality of our matching sample, we include only those pairs (77 pairs) with a CMS of less than three in our study sample.

equality of the mean between the two groups are 8.49 and 11.47, respectively, during the pre and post tick-size change periods.) These results support the view that Nasdaq dealers have less incentive to compete on price before the implementation of the new OHR. The table also shows that while the proportions of even-eighth quotes declined significantly after the tick-size reduction for the OHR stocks, such is not the case for the non-OHR stocks. These results are consistent with our earlier finding that the tick-size reduction led to smaller spreads only for the OHR stocks.

5. Effects of the tick-size change on depths

5.1. Tick size and depths

Previous studies show that the tick-size reduction results in a significant decrease in the quoted depth on the TSE (see, e.g., Harris, 1997) and the NYSE (see, e.g., Goldstein and Kavajecz, 2000). In this section we analyze how the tick-size reduction affects the quoted depth of Nasdaq stocks and compare the results with those from the control sample of NYSE stocks. Because the price-time priority rule is enforced on the TSE and NYSE but not on Nasdaq, the results of the present study shed further light on how the priority rule affects the impact of the tick-size change on quoted depths. In addition we examine how the new OHR alter the impact of the tick-size reduction on quoted depths.

The TAQ database reports only the largest, not the aggregate, depth at the inside for Nasdaq issues whereas it reports the aggregate depth (specialist depth plus all the limit orders at the quoted price) for NYSE issues. Hence, the cross-market comparison of quoted depths is not meaningful. We analyze the effect of tick size on depths, however, by performing the before-and-after comparison of quoted depths around the date of the tick-size change within each market.

Table 5 shows the effects of the tick-size change on the quoted depths for our Nasdaq stocks and the control sample of NYSE stocks. Panel A shows the time-weighted depth (in round

lots) during the pre and post tick-size change periods. We report two depth figures: the average time-weighted depth for our entire study sample of stocks (depth1) and the average time-weighted depth for those stocks with at least 300 trades (depth2). Note that the tick-size reduction has a significant effect on the quoted depth for the control sample of NYSE stocks. The average depth during the pre tick-size reduction period is 122.0 while the corresponding figure during the post tick-size change period is only 83.1. The observed difference (38.9) in the depth between the two periods is statistically significant. We obtain similar results from stocks with at least 300 trades. These results are qualitatively similar to those reported in previous studies (see, e.g., Bollen and Whaley, 1998 and Goldstein and Kavajecz, 2000) and indicate that the tick-size reduction has a significant effect on quotation size in hybrid markets.

Table 5 shows that the tick-size change has only a marginal effect on the depth of Nasdaq stocks. The average depth during the pre tick-size change period is 20.3 whereas the corresponding figure after the tick-size change is 20.9. While the average depth of Nasdaq issues during the post tick-size change period is slightly greater than the corresponding figure during the pre tick-size change period, the difference is small and statistically insignificant. Overall, our empirical results indicate that the smaller tick size resulted in narrower spreads for those Nasdaq issues that were subject to the OHR without adversely affecting the quoted depth. Hence, the tick-size reduction led to an increase in the liquidity of Nasdaq issues.[18]

5.2. Order handling rules and the effect of the tick-size change on Nasdaq depths

We now examine whether competition from limit order traders has changed the way the tick-size reduction affects the quoted depth. For this, we calculate the difference in quoted depth between the pre and post tick-size change periods for those Nasdaq issues subject to the new OHR before the tick-size reduction. Similarly, we calculate the difference in quoted depth

[18] This conclusion has limitation as the TAQ database shows only the largest depth for Nasdaq issues.

between the pre and post tick-size change periods for those Nasdaq issues that were subject to the OHR after the tick-size reduction.

Panel B of Table 5 shows that the average time-weighted depth during the pre tick-size change period is 26.4 and the corresponding figure during the post tick-size change period is 25.0 for the OHR stocks. The result of t-test shows that the observed decline in depth (1.4) is not statistically significant. For the sample of Nasdaq issues that were not subject to the new OHR at the time of the tick-size change, the average time-weighted depths during the pre and post tick-size change periods are 19.6 and 19.8, respectively. The result of t-test indicates that the observed change in depth (-0.2) is not significantly different from zero. We obtain similar results from stocks with at least 300 trades. These results suggest that the tick-size reduction has no impact on quoted depths, regardless of whether or not Nasdaq dealers were subject to competition from limit order traders.

Finally, our empirical results show that the average depth of the OHR stocks is larger (significant at the 1%) than the average depth of the non-OHR stocks. The observed increase in depth may indicate that after the OHR change, market makers started to show their trading interests (i.e., desired trade sizes) more frequently, while before the OHR change, most market makers posted only the mandatory minimum depth. The increase in depth may also indicate that large limit orders started to set the inside spread after the OHR change.[19]

6. Concluding remarks

In this study we examine the effect of the tick-size change on the spreads and depths of Nasdaq issues. While the effect of tick size on the liquidity of stocks traded in purely order-

[19] Barclay et al. (1999) report mixed results for the effect of the OHR change on depths. For the January 20 sample, the study finds that the aggregate quoted depths at the inside market is virtually unaffected by the rule change. For those stocks phased-in on February 10, however, the study finds that the aggregate depth after the rule change is significantly greater than the corresponding figure before the rule change. Our

driven or hybrid markets has been well documented, the corresponding effect in dealer markets without a price-time priority rule has received relatively little attention. While researchers conjecture that the impact of the tick-size change on Nasdaq spreads will be insignificant before the OHR change, no direct evidence is available on this issue.

Our empirical results indicate that the smaller tick size narrows spreads on both the NYSE and Nasdaq. When we separate Nasdaq stocks into two groups according to whether the tick-size change preceded or followed the order handling rules change, we find that the tick-size change has no impact on the spread of stocks for which the tick-size change preceded the order handling rules change. These results suggest that Nasdaq dealers did not compete on price for order flow prior to the order handling rules change. This is not surprising because Nasdaq dealers had little incentive to do so without a time priority rule.

For the group of Nasdaq issues that were subject to the new order handling rules prior to the tick-size change, however, we find that the tick-size reduction has a significant effect on spreads. This result suggests that the new order handling rules effectively subject Nasdaq dealers to competition from limit order traders and thereby force them to offer competitive quotes. In addition, we find that the tick-size change did not adversely affect quotation size on Nasdaq.

The Nasdaq Stock Market began its decimal test phase on March 12, 2001 with 14 securities, followed by another 197 securities on March 26, 2001. All remaining Nasdaq securities converted to decimal trading on April 9, 2001. Some suggest that a smaller price increment would shift power from public traders to professional traders by making it easier for professionals to step in front of public limit orders. As a result, public traders will display their orders less often and switch from limit order strategies to market order strategies. Others argue that decimal prices are easier to use than fractional prices and that a smaller price increment

---

results are not directly comparable to Barclay et al.'s because the TAQ database reports only the largest, not the aggregate, depth at the inside market for Nasdaq issues.

would encourage price competition and narrow bid-ask spreads. The results of the present study suggest that decimalization is likely to narrow spreads.

The early evidence is consistent with our prediction. Nasdaq reports that both quoted and effective spreads fell by an average of 50% for most stocks.[20] The report also indicates that small retail orders benefited the most from the reduced spreads and that large institutional orders' transactions costs do not appear to have increased. In addition, Chakravarty, Harris, and Wood (2001a, 2001b), Bessembinder (2002), and Chung, Van Ness, and Van Ness (2002) find a significant decrease in spreads on both the NYSE and Nasdaq after decimalization.

[20]The impact of decimalization on the Nasdaq Stock Market, Final Report to the SEC, Nasdaq Economic Research, The Nasdaq Stock Market, Inc., June 11, 2001.

References

Ahn, H., Cao, C., Choe, H., 1996. Tick size, spread, and volume. Journal of Financial Intermediation 5, 2-22.

Ahn, H., Cao, C., Choe, H., 1998. Decimalization and competition among stock markets: evidence from the Toronto Stock Exchange cross-listed securities. Journal of Financial Markets 1, 51-87.

Atkins, A., Dyl, E., 1997. Market structure and reported trading volume: Nasdaq versus the NYSE. Journal of Financial Research 20, 291-304.

Bacidore, J., 1997. The impact of decimalization on market quality: an empirical investigation of the Toronto Stock Exchange. Journal of Financial Intermediation 6, 92-120.

Barclay, M., Christie, W., Harris, J., Kandel, E., Schultz, P., 1999. The effects of market reform on the trading costs and depths of Nasdaq stocks. Journal of Finance 54, 1-34.

Bessembinder, H., 2000. Tick size, spreads, and liquidity: an analysis of Nasdaq securities trading near ten dollars. Journal of Financial Intermediation 9, 213-239.

Bessembinder, H., 2002. Trade execution costs and market quality after decimalization. Working paper. University of Utah.

Bollen, N., Whaley, R., 1998. Are "teenies" better? Journal of Portfolio Management 25, 10-24.

Chakravarty, S., Harris, S., Wood, R., 2001a. Decimal trading and market impact. Working Paper. University of Memphis.

Chakravarty, S., Harris, S., Wood, R., 2001b. Decimal trading and market impact: the Nasdaq experience. Working Paper. University of Memphis.

Chung, K., Van Ness, B., Van Ness, R., 1999. Limit orders and the bid-ask spread. Journal of Financial Economics 53, 255-287.

Chung, K., Van Ness, B., Van Ness, R., 2001. Can the treatment of limit orders reconcile the differences in trading costs between NYSE and Nasdaq issues? Journal of Financial and Quantitative Analysis 36, 267-286.

Goldstein, M., Kavajecz, K., 2000. Eighths, sixteenths and market depth: changes in tick size and liquidity provision on the NYSE. Journal of Financial Economics 56, 125-149.

Chung, K., Van Ness, B., Van Ness, R., 2002. Trading costs and quote clustering on the NYSE and Nasdaq after decimalization. Working paper. The State University of New York at Buffalo.

Griffiths, M., Smith, B., Turnbull, D., White, R., 1998. The role of tick size in upstairs trading and downstairs trading. Journal of Financial Intermediation 7, 393-417.

Harris, L., 1994. Minimum price variations, discrete bid-ask spreads, and quotation sizes. Review of Financial Studies 7, 149-178.

Harris, L., 1997. Decimalization: a review of the arguments and evidence. Working Paper. University of Southern California.

Kavajecz, K., 1999. A specialist's quoted depth and the limit order book. Journal of Finance 54, 747-771.

Lee. C., Ready, M., 1991. Inferring trade direction from intraday data. Journal of Finance 46, 733-746.

Porter, D., Weaver, D., 1997. Decimalization and market quality. Financial Management 26, 5-26.

Simaan, Y., Weaver, D., Whitcomb, D., 1998. The quotation behavior of ECNs and Nasdaq market makers. Working Paper. Baruch College, CUNY.

Stoll, H., 2000. Friction. Journal of Finance 55, 1479-1514.

Van Ness, R., Van Ness, B., Pruitt, S., 2000. The impact of the reduction in tick increments in major U.S. markets on spreads, depth, and volatility. Review of Quantitative Finance and Accounting 15, 153-167.

Weston, J., 2000. Competition on the Nasdaq and the impact of recent market reforms. Journal of Finance 55, 2565-2598.

Table 1
Descriptive statistics for 518 Nasdaq stocks and the control sample of NYSE stocks

To obtain the control sample of NYSE stocks, we first calculate the composite match score (CMS) for each Nasdaq stock against each of 2,242 NYSE socks in our sample: $CMS = \Sigma[(Y_k^N - Y_k^Y)/\{(Y_k^N + Y_k^Y)/2\}]^2$, where Y_k represents one of the five stock attributes, the superscripts, N and Y, refer to Nasdaq and NYSE, respectively, and Σ denotes the summation over $k = 1$ to 5. Then, for each Nasdaq stock, we select the NYSE stock with the lowest score. Once a NYSE stock is matched with a Nasdaq issue, the NYSE stock is no longer considered for subsequent matches. This procedure results in 518 pairs of Nasdaq and NYSE stocks that are reasonably similar in their attributes. We measure share price by the average daily closing price and return volatility by the standard deviation of daily returns during 30 trading days before the tick-size change. We measure trade size by the average dollar transaction size. We measure firm size by the market value of equity (in $millions) on May 31, 1997.

				Percentile				
Variable	Exchange	Mean (t-value[a])	Standard deviation	5	25	50	75	95
Share price ($)	Nasdaq	24.98 (0.13)	11.69	12.28	16.33	21.96	31.02	46.10
	NYSE	24.89	13.11	11.23	15.95	20.91	30.39	54.04
Number of trades	Nasdaq	50.66 (0.64)	108.42	3.80	10.43	23.73	51.07	186.90
	NYSE	48.55	92.46	3.70	10.57	22.57	51.30	158.73
Trade size ($)	Nasdaq	38,946 (-1.07)	11,917	20,709	32,756	51,251	86,941	
	NYSE	40,312	34,933	11,396	19,958	32,688	54,155	108,011
Return volatility	Nasdaq	0.0231 (1.62)	0.0131	0.0110	0.0154	0.0203	0.0273	0.0432
	NYSE	0.0215	0.0144	0.0081	0.0137	0.0182	0.0248	0.0404
Market value of equity	Nasdaq	656.2 (-0.94)	979.8	53.8	139.8	321.6	702.8	1,997.8
	NYSE	691.6	1,196.0	52.3	141.3	327.6	734.7	2,441.6

[a]The t-statistic testing the equality of the mean between Nasdaq and NYSE stocks.

Table 2
The effects of the tick-size change on the spreads of Nasdaq stocks and the control sample of NYSE stocks

We use three measures of trading costs in this study: the quoted dollar spread, quoted percentage spread, and effective spread. The quoted dollar spread is the difference between the posted ask and bid prices. The quoted percentage spread is obtained by dividing the quoted dollar spread by the quote midpoint. We calculate the effective spread using the following formula: Effective spread$_{it}$ = $2D_{it}(P_{it} - M_{it})$, where P_{it} is the transaction price for security i at time t, M_{it} is the midpoint of the most recently posted bid and ask quotes for security i, and D_{it} is a binary variable which equals +1 for customer buy orders and -1 for customer sell orders. The effective spread measures the actual execution cost paid by the trader. This table shows the average time-weighted dollar and percentage spreads and the average trade-weighted effective spread during the pre and post tick-size change periods.

	Nasdaq stocks				Control sample of NYSE stocks			
	Before the change	After the change	Difference (before-after)	t-value[a]	Before the change	After the change	Difference (before-after)	t-value[a]
A. Results from the whole study sample (N = 518)[b]								
$ Spread	0.4855	0.4655	0.0200	3.26*	0.2102	0.1918	0.0184	3.62*
% Spread	0.0215	0.0191	0.0024	3.34*	0.0097	0.0082	0.0015	6.01*
E. Spread	0.4072	0.3829	0.0243	2.94*	0.1784	0.1502	0.0282	5.68*
B. Results from stocks with at least 300 trades (N = 480)[b]								
$ Spread	0.4589	0.4333	0.0256	3.43*	0.1997	0.1786	0.0211	5.38*
% Spread	0.0203	0.0178	0.0025	3.78*	0.0093	0.0077	0.0016	6.45*
E. Spread	0.3888	0.3640	0.0248	3.17*	0.1699	0.1420	0.0279	8.89*

*Significant at the 1% level
[a]The t-statistic testing the equality of the mean between the pre and post tick-size change periods.
[b]The number of matching stocks.

Table 3
Comparisons of Nasdaq spreads between stocks that were subject to the new order handling rules (OHR) before the tick-size change and those subject to the rules after the tick-size change

To examine whether the impact of the tick-size reduction on Nasdaq spreads differs depending on whether dealers were subject to competition from public limit orders, we compare spread changes between stocks that were subject to the new order handling rules (OHR) before the tick-size change and those subject to the rules after the tick-size change. We obtain the control sample of 83 NYSE stocks for Nasdaq stocks that were subject to the OHR at the time of the tick-size reduction using the same procedure described in Section 3. Likewise, we obtain the control sample of 388 NYSE stocks for Nasdaq stocks that were subject to the OHR only after the tick-size change. We show the mean spread during the pre and post tick-size change periods, respectively, and the difference between the two periods.

	Nasdaq stocks subject to the new OHR before the tick-size change (the OHR stocks)				Nasdaq stocks subject to the new OHR after the tick-size change (the non-OHR stocks)			
	Before the change	After the change	Difference (before-after)	t-value[a]	Before the change	After the change	Difference (before-after)	t-value[a]
A. Results from the Nasdaq study sample								
$ Spread	0.3209	0.2808	0.0401	3.46*	0.5373	0.5548	-0.0075	-0.37
% Spread	0.0106	0.0086	0.0020	3.49*	0.0256	0.0247	0.0009	1.36
E. Spread	0.2895	0.2519	0.0376	3.08*	0.4457	0.4410	0.0047	0.31
B. Results from the control sample of NYSE stocks								
$ Spread	0.1828	0.1506	0.0322	3.79*	0.2172	0.2022	0.0150	3.65*
% Spread	0.0067	0.0053	0.0014	3.34*	0.0108	0.0093	0.0015	5.35*
E. Spread	0.1598	0.1248	0.0350	4.89*	0.1839	0.1584	0.0255	5.44*

*Significant at the 1% level
[a]The t-statistic testing the equality of the mean between the pre and post tick-size change periods.

Table 4
Matching sample comparisons of Nasdaq spreads between stocks that were subject to the new order handling rules (OHR) before the tick-size change and those subject to the rules after the tick-size change

To examine whether the impact of the tick-size reduction on Nasdaq spreads differs depending on whether dealers were subject to competition from public limit orders, we replicate Table 3 using Nasdaq stocks that were subject to the new OHR before the tick-size reduction and their matching Nasdaq stocks that were subject to the new OHR after the tick-size reduction. To obtain matching samples of Nasdaq stocks, we calculate the composite match score (CMS) for each Nasdaq stock that was subject to the new OHR before the tick-size change against each of 1,525 Nasdaq issues that were subject to the new OHR after the tick-size change. Then, for each stock from the first group, we select the stock from the second group that has the lowest score. This procedure results in 77 pairs of Nasdaq stocks. We show the mean spread during the pre- and post tick-size change periods, respectively, and the difference between the two periods.

	Nasdaq stocks subject to the new OHR before the tick size change (the OHR stocks)				Nasdaq stocks subject to the new OHR after the tick size change (the non-OHR stocks)			
	Before the change	After the change	Difference (before-after)	t-value[a]	Before the change	After the change	Difference (before-after)	t-value[a]
$ Spread	0.2956	0.2626	0.0330	2.98*	0.4856	0.4794	0.0062	0.08
% Spread	0.0126	0.0101	0.0025	3.20*	0.0184	0.0164	0.0020	1.81
E. Spread	0.2670	0.2373	0.0297	3.21*	0.4083	0.3864	0.0219	0.42
Proportion of even-eighth quotes	0.5903	0.5111	0.0792	5.35*	0.6974	0.6717	0.0257	1.21

*Significant at the 1% level
[a]The t-statistic testing the equality of the mean between the pre and post tick-size change periods.

Table 5
The effects of the tick-size change on the depths of Nasdaq stocks and the control sample of NYSE stocks

Panel A shows the time-weighted depth (in round lots) during the pre and post tick-size change periods for our Nasdaq sample and the control sample of NYSE stocks, respectively. We report two depth figures: the average time-weighted depth for our entire study sample of stocks (depth1) and the average time-weighted depth for those stocks with at least 300 trades (depth2). Panel B shows whether competition from limit order traders has shifted the way the tick-size reduction affects the quoted depth. We show the difference in quoted depth between the pre and post tick-size change periods for those Nasdaq issues subject to the new OHR before the tick-size reduction. Similarly, we show the difference in quoted depth between the pre and post tick-size change periods for those Nasdaq issues that were subject to the OHR after the tick-size reduction.

A. Quoted depths of Nasdaq stocks and the control sample of NYSE stocks before and after the tick-size change

	Nasdaq stocks				Control sample of NYSE stocks			
	Before the change	After the change	Difference (before-after)	t-value[a]	Before the change	After the change	Difference (before-after)	t-value[a]
Depth1	20.3	20.9	-0.6	-1.51	122.0	83.1	38.9	4.02*
Depth2	20.7	21.3	-0.6	-1.52	128.6	86.4	42.2	4.06*

B. Quoted depths of Nasdaq stocks before and after the tick-size change

	Nasdaq stocks subject to the new OHR before the tick size change (the OHR stocks)				Nasdaq stocks subject to the new OHR after the tick size change (the non-OHR stocks)			
	Before the change	After the change	Difference (before-after)	t-value[a]	Before the change	After the change	Difference (before-after)	t-value[a]
Depth1	26.4	25.0	1.4	1.28	19.6	19.8	-0.2	-0.45
Depth2	26.4	25.0	1.4	1.28	18.0	18.3	-0.3	-0.60

*Significant at the 1% level
[a]The t-statistic testing the equality of the mean between the pre and post tick-size change periods.