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Tick Size, Spreads, and Liquidity: An Analysis of Nasdaq Securities Trading near Ten Dollars[1]

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Quoted and effective bid–ask spreads on Nasdaq are two to four cents per share narrower, *ceteris paribus*, when stocks trade with a smaller tick size below $10 per share. There is no evidence of a reduction in liquidity with the smaller tick size. The largest spread reductions occur for stocks whose market makers avoid odd-eighth quotes. This finding provides support for models implying that changes in the tick size can affect equilibrium spreads on a dealer market and indicates that the relation between tick size and market quality is more complex than the imposition of a constraint on minimum spread widths. *Journal of Economic Literature* Classification Numbers: G29, D34, N20. © 2000 Academic Press

1. INTRODUCTION

In standard textbook models of competitive industries, economic efficiency is attained by allowing supply and demand conditions to freely determine market prices. Nevertheless, virtually all securities markets restrict prices to fall on a discrete grid by imposing *minimum tick* rules to establish the smallest allowable price increment. Critics of these rules, including Ricker (1996) and Peake (1993) have focused in particular on the spread between market makers' bid and ask prices, which can be viewed as the price of liquidity for small trades. They note that tick size rules constrain the spread to be at least as wide as the mandated tick size, potentially increasing market-maker revenues and investor trading costs.

Harris (1994, 1996, 1997) has cautioned that the economics of liquidity provision need to be considered carefully when evaluating the role of tick size rules. The

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tick size potentially affects market makers' and public investors' willingness to supply liquidity in the form of binding quotations and limit orders. For example, in markets that enforce time priority, the cost of obtaining order precedence by improving on the existing quotation is reduced with a smaller tick size, which could adversely affect incentives to expose trading interest in the form of quotations or limit orders.

If liquidity supply is reduced then traders whose orders exceed the quote size could pay higher trade execution costs, even if quoted spreads are narrower. Further, reductions in liquidity supply could be associated with increased price volatility or reversals of price changes. Particular concern has been expressed (see, for example, Ceron (1999)) that small-capitalization stocks will suffer reductions in liquidity with a smaller tick size. The issue remains timely. For example, the major U.S. stock exchanges have committed to pricing in decimals during the year 2000, but the new decimal-based tick size is as yet undetermined.

It is an empirical question whether market quality is enhanced by a reduction in tick sizes. Several studies have investigated the issue by examining market quality before and after market-wide tick size changes. In April 1996, the Toronto Stock Exchange reduced its minimum tick for stocks priced over \$5 from \$0.125 to \$0.05. A set of studies, reviewed by Harris (1997), report reductions in quoted spreads for the affected Toronto stocks of between 2 and 5 cents per share, but also document reductions in quote sizes ranging from 26 to 52%.[2] The major U.S. stock exchanges, including the New York Stock Exchange, the Nasdaq Stock Market, and the American Stock Exchange reduced tick sizes from 1/8 dollar to 1/16 dollar during May and June of 1997. Ricker (1998) and Goldstein and Kavajecz (2000) document a reduction in quoted NYSE spreads, while Jones and Lipson (2000) show that quoted Nasdaq spreads declined, and Ronen and Weaver (1998) report narrower spreads after the tick size reduction on the American Stock Exchange. However, Goldstein and Kavajecz (2000) examine the NYSE limit order book and report that quantity of shares posted as limit orders declined with the smaller tick size, suggesting a reduction in liquidity. Jones and Lipson (2000) document that total trading costs for a set of institutional investors who execute large trades actually increased after the tick size reduction. In contrast, Ronen and Weaver (1998) report that market quality on the American Stock Exchange is not hindered by the smaller tick size.

While the group of before-versus-after studies that examine tick size reductions are informative, they are also subject to an inherent limitation. Each market-wide tick size reduction comprises but a single event, and the U.S. events in particular are closely clustered in calendar time. It is difficult to fully control for the possibility of contemporaneous changes in other variables, such as the economy-wide rate of information flow, that potentially affect spreads and liquidity.

[2] These studies include Ahn *et al.* (1998), Bacidore (1996), Chung *et al.* (1997), Griffiths *et al.* (1997), Huson *et al.* (1997) and Porter and Weaver (1997). The reduction in quote sizes may simply reflect an upward-sloping liquidity supply schedule and need not imply that liquidity supply has been reduced.

This study provides an alternate empirical analysis of tick size changes, focusing on a set of 765 Nasdaq-listed common stocks whose tick size changed as their share prices passed through \$10 during calendar year 1995. Though there was apparently no written rule, the convention on Nasdaq during 1995 was to use tick sizes of 1/8 dollar for bid quotations at or above \$10 per share and 1/32 dollar for bid quotations below \$10 per share. I use these endogenous tick size change events to provide evidence on several questions, including: (1) How are quoted and effective bid–ask spreads affected by changes in tick size? (2) Is market liquidity, as measured by return volatility and price reversals, affected by changes in tick size? (3) Is there meaningful cross-sectional variation in the changes in spreads and liquidity associated with tick size changes?

The research approach used here has some inherent advantages, as well as some disadvantages, compared to the before-versus-after studies. The main advantage is that stock prices pass through \$10 on different dates, implying a reduced likelihood that comparisons will be affected by contemporaneous changes in market-wide factors affecting spreads and liquidity and allowing for a substantially larger effective sample size. Also, it is possible to examine both the relaxation of and the tightening of the constraint that the tick size imposes on quotations, by analyzing cases where stock prices increase or decrease through \$10.

The key disadvantage of this research design is that the tick size changes are not predictable and may individually turn out to be temporary rather than permanent, as the share price could again pass through \$10. I attempt to reduce the effect of short-lived tick size changes contained in the sample by examining a subset of stocks whose share price passed through \$10 only once and by considering separately events where share prices did not again cross \$10 for specified time intervals. A second disadvantage is that the change in share price required for the tick size to change may itself reflect new information that affects liquidity supply. I use a regression approach to control for simultaneous changes in trading activity and share price, in order to estimate the independent effect of the tick size change.

Harris (1996) has used a similar approach, examining stocks traded on the Toronto Stock Exchange and the Paris Bourse, where the tick size also varies with share price.[3] He focuses mainly on limit order traders' willingness to expose their trading interest, documenting a reduction in displayed order size with a smaller tick size. He also considers bid–ask spreads and quote sizes for 26 Paris stocks whose tick size changed due to share price changes during the sample period, documenting a reduction in spreads and quote sizes with the smaller tick size. This study extends the methodology to a much larger sample, considers tick increases and tick decreases separately, conducts cross-sectional analysis of changes in liquidity with the tick size change, and also examines return volatility around the tick size change.

[3] The tick size varies with share price on the NYSE as well, but the break point is \$1 per share. Since virtually all NYSE stocks trade at much higher share prices, large selection biases would apply to NYSE stocks trading with more than one tick size.

The results of this study confirm that bid–ask spreads are narrower with the smaller tick size. Both quoted and effective (which allow for executions within the quotations) bid–ask spreads are approximately 3 to 5 cents narrower with the smaller tick size. Allowing for contemporaneous changes in share price and trading activity indicates that the tick size change has an independent effect on quoted and effective spreads of 2 to 3 cents per share. There is little evidence that the impact on spreads differs for events that increase the tick size compared to events that decrease the tick size. No evidence of reductions in liquidity is found. In contrast, return volatility is on average slightly lower with the smaller tick size, and the tick size has no observable effect on the degree to which intraday price changes are subsequently reversed.

There is interesting cross-sectional variation in the trading cost reductions with the smaller tick size. The largest reductions in trade execution costs are for firms whose market makers avoid the use of odd-eighth quotations when the tick size is 1/8 and for which the average spread exceeds 60 cents. This result is surprising when viewed in terms of the most readily apparent link between trading costs and tick size: that bid–ask spreads are constrained to be at least as large as the tick size. It does, however, provide support for models such as Kandel and Marx (1997) and Dutta and Madhavan (1997), which imply that changes in the tick size can affect equilibrium spreads on a dealer market. It also shows that the relation between tick size and market quality is more complex than the imposition of a constraint on minimum spread widths.

This paper is organized as follows. Section 2 describes the sample selection criteria and the research design employed. Section 3 provides evidence of the effect of tick size changes on average bid–ask spreads, while Section 4 assesses cross-sectional variation in bid–ask spread reductions. Section 5 assesses whether there is a reduction in liquidity with the smaller tick size, and Section 6 concludes.

2. RESEARCH DESIGN

A. *Sample Selection*

The key requirement for inclusion in this study is that the sample stocks should trade on Nasdaq at share prices both above and below \$10. The sample is drawn from calendar year 1995, which allows the use of data that is relatively recent, but precedes the market-wide Nasdaq tick size reduction. I use the CRSP tapes to identify those common stocks that are listed on Nasdaq throughout calendar year 1995 and that close with share prices above \$10 on at least ten days and with share prices below \$10 on at least 10 days. 773 stocks meet these criteria. Of these, I eliminate eight stocks that traded less than 10 times during the year, leaving a final sample of 765 common stocks, a listing of which is available from the author on request.

B. Tick Size Change Events

These stocks experienced a total of 2849 events where the closing share price passed through $10 and remained there for at least one subsequent day. Of these, 1513 events involved a share price and tick size increase, while 1336 events involved a share price and tick size decrease. Many of the events were short-lived. Reversals of the tick size change occurred on the second day after the event in 976 cases. Reversals occurred within five (ten) days of the event in 1502 (1895) cases. A total of 176 tick size change events were not reversed before the end of the sample period.

It may take time for market makers and traders to learn whether a tick size change is permanent and to learn to exploit the change in opportunities and costs associated with a tick size change. This implies that events of longer duration may be more useful in assessing the full effect of a tick size change. I examine bid–ask spreads and volatility measures for varying periods of time around tick size change events, including horizons of 1, 5, 10, 20, and 40 days before and after. To be considered in sample, it is required that the stock experience no other event within the indicated time window. Shorter horizons allow for larger effective sample sizes, while larger horizons allow more permanence and more time for market participants to react to the tick size change. I also consider separately the subsample of 176 stocks whose share price passed through $10 only one time during 1995.

C. Measures of Trading Costs

I obtain trade and quote data for calendar year 1995 from the Trade and Quote (TAQ) database and examine two measures of trade execution costs.[4] The first is the quoted bid–ask spread. The empirical results reported are based on weighted average spreads, where the weighting variable is the elapsed time before a quotation is updated.[5] Most retail trades on the Nasdaq market are automatically executed at the inside quote, implying that the quoted spread is an accurate measure of trade execution costs. In the interest of completeness, I also report on effective bid–ask spreads, measured for each trade as twice (to capture the implied round-trip cost) the difference between the trade price and the midpoint of the bid and ask

[4] The quotation data reflect the best or "inside" quotations posted by Nasdaq dealers rather than individual dealer quotes. A small number of trades and quotes are filtered because of a high likelihood that they reflect errors or because they represent unusual circumstances. Trades are omitted if they are indicated in the TAQ database to be coded out of time sequence or as involving an error or a correction. Trades indicated to be exchange acquisitions or distributions, trades that involve nonstandard settlement, and trades that are not preceded by a valid same-day are omitted as well. I also omit trades that involve price changes (since the prior trade) of 25% or more. Quotes are omitted if either ask or bid prices are nonpositive and if the differential between the ask and bid prices exceeds $4 or is nonpositive. The postfiltering sample contains includes 9.11 million trades and 1.55 million quotations.

[5] I also examine trade-weighted average spreads, based on recording the spread at the time each trade is executed and averaging across trades. Results are very similar to those reported.

quotations at the time of the trade.[6] This measure potentially reflects reductions in average trading costs attributable to executions within the quotes. However, to the extent that those trades executed within the public quotations reflect interdealer trades rather than public orders, narrower effective spreads may not reflect lower execution costs to the public.

Most of the empirical results reported here are based on quoted and effective spreads measured on an absolute basis, rather than as a percentage of share price. This decision reflects that share varies with tick size in this sample by construction. Testing whether trade execution costs as a percentage of price vary across tick sizes is equivalent to testing whether the proportional reduction in trade execution costs exceeds the reduction in average share price. Further, recent and proposed market-wide tick size changes would not be accompanied by immediate share price changes of a similar magnitude.[7] As a consequence, the analysis of absolute changes in spreads is likely to be most informative for purposes of projecting the effects of such market-wide tick size changes. Section 3B below examines formally whether share price variation can explain the change in spreads that occur when the tick size changes.

D. *Measures of Liquidity*

Testing whether the tick size affects liquidity provision is complicated by the fact that liquidity is not directly observable. One possible form that a lack of liquidity could take is an increase in volatility. Average return standard deviations are computed for each event from the over $10 and under $10 subsamples. I report the cross-sectional median volatility for each subsample and also record for each event whether volatility is increased or decreased in the under $10 sample as compared to the over $10 sample. The null hypothesis of equal volatility is evaluated using a Fisher sign test of the hypothesis that the percentage of firms experiencing an increase in volatility equals 50.

While an observed change in return volatility after tick size changes could reflect shifts in liquidity supply, it could also result from changes in the rate of information flow. As a supplemental test, I use variance ratios constructed from intraday returns measured over differing time horizons to test for intraday price reversals. Systematic reversals of prices would be observed if order flows or information

[6] Lee and Ready (1991) note that trades are often reported with a delay and recommend lagging trades by five seconds before comparing to quotations. Hasbrouck *et al.* (1993) report a median trade-reporting delay for NYSE stocks of 14 s. To be conservative, I lag trade times by 20 s before comparing to quotations. Schultz (1997) reports that trade reporting lags for Nasdaq trades may be severe, implying that even a 20-s lag may not provide fully accurate measures of effective spreads. He also notes that reporting lags are less severe for trades after 11 a.m. I also estimate average effective spreads while excluding trades completed before 11 a.m. and find that the effect of tick size changes is very similar to those reported for the full sample.

[7] However, Angel (1997) argues that firms split or reverse-split their stock over time to attain an optimal share price relative to the tick size. If so, tick size reductions could eventually be accompanied by share price reductions of a similar magnitude.

temporarily push prices beyond their longer-term equilibrium and would be indicative of a lack of liquidity. In contrast, increased information flows that lead to permanent price changes would increase return volatility, but would not alter variance ratios.

3. EMPIRICAL EVIDENCE ON BID–ASK SPREADS AROUND TICK SIZE CHANGES

A. Average Spreads

Table I reports average (across firms and days) quoted and effective bid–ask spreads before and after tick size changes, for the full sample and several subsamples. Panel A reports average spreads, based on the number of times the stock price passed through $10 during 1995. Panel B reports average spreads by crossing event, on the basis of the elapsed time between events. Panel C reports average spreads by stock, based on market-maker quotation behavior. Results on Panels A and C use all trading days during 1995, while the event-specific means on Panel B use only observations within the indicated event window. For example, results for events where the stock price remained over or under $10 for at least five trading days are based on observations from five days before to five days after the crossing event.

Full sample results reported on Panel A of Table I indicate that quoted spreads are 3.9 cents narrower and effective spreads 3.6 cents narrower with the smaller Nasdaq tick size. However, spreads as a fraction of share price are substantially greater with the smaller tick size, indicating that the reduction in spreads is less than proportional to the reduction in share price.

Of the 765 firms in the sample, 176 experienced only a single 1995 crossing of share price through $10. These firms experienced a larger reduction in quoted spreads with the smaller tick size, averaging 5.9 cents per share. This likely reflects that market makers were able to forecast to a degree, or became aware as time elapsed, that the tick size changes for these stocks were permanent. One hundred nine sample stocks experienced more than ten crossings of closing share price through $10 during 1995. The average reduction in bid–ask spreads with the smaller tick size was 3.2 cents per share for these stocks.

Results reported on Panel B of Table I show that the change in average spreads is greater when events are studied over longer horizons of 20 and 40 days compared to short horizons of one or five days. For events with at least single-day duration, quoted spreads are 1.6 cents less with the smaller tick size. For events with five-day durations spreads are 2.2 cents narrower with the smaller tick size. As the event horizon is increased to 10, 20, and 40 days the observed spread reductions increase to 3.0, 3.5, and 3.6 cents per share. Figures 1 to 4 display cross-sectional average bid–ask spreads for events of 5- to 40-day durations, on a day-by-day basis. These indicate that the most marked changes in spreads occur within about two days of

TABLE I
Average Bid–Ask Spreads and Trading Volume around Nasdaq Share Prices of $10 during 1995

	Quoted spread (cents)	Quoted spread (%)	Effective spread (cents)	Effective spread (%)	Trading volume
Panel A: Averages across firms based on number of times share price passed through $10					
All 765 sample firms					
Over $10	47.9	3.95	38.6	3.18	87.9
Under $10	44.0	5.40	35.0	4.29	63.1
Difference	−3.9	1.45	−3.6	1.11	−24.8
176 firms whose stock price passed through $10 once during sample					
Over $10	54.1	4.09	44.6	3.38	73.1
Under $10	48.2	6.41	39.5	5.25	49.1
Difference	−5.9	2.32	−5.1	1.87	−24.0
293 firms whose stock price passed through $10 two to five times during sample					
Over $10	50.7	4.23	40.7	3.41	78.9
Under $10	47.1	5.71	37.5	4.53	58.3
Difference	−3.6	1.48	−3.3	1.12	−20.6
187 firms whose stock price passed through $10 six to ten times during sample					
Over $10	42.6	3.66	33.7	2.91	100.8
Under $10	39.5	4.62	30.8	3.60	70.2
Difference	−3.1	0.96	−2.9	0.69	−30.6
109 firms whose stock price passed through $10 more than ten times during sample					
Over $10	39.5	3.44	31.3	2.73	114.2
Under $10	36.3	4.25	28.0	3.27	86.7
Difference	−3.2	0.81	−3.3	0.54	−27.6
Panel B: Averages across events, based on days between events					
2849 events where the stock price remained over or under $10 for at least 1 trading day					
Over $10	45.8	4.35	36.6	3.47	119.2
Under $10	44.2	4.59	34.3	3.57	107.2
Difference	−1.6	0.24	−2.3	0.10	−12.0
1301 events where the stock price remained over or under $10 for at least 5 trading days					
Over $10	47.8	4.42	38.7	3.57	100.7
Under $10	45.6	4.87	36.0	3.84	82.3
Difference	−2.2	0.45	−2.7	0.27	−18.4
796 events where the stock price remained over or under $10 for at least 10 trading days					
Over $10	49.5	4.47	40.1	3.62	93.1
Under $10	46.5	5.06	36.8	3.99	74.5
Difference	−3.0	0.59	−3.3	0.37	−18.6
461 events where the stock price remained over or under $10 for at least 20 trading days					
Over $10	50.2	4.42	40.7	3.59	80.9
Under $10	46.7	5.25	37.2	4.16	61.6
Difference	−3.5	0.83	−3.5	0.57	−19.3
252 events where the stock price remained over or under $10 for at least 40 trading days					
Over $10	50.1	4.27	40.7	3.48	75.5
Under $10	46.5	5.37	37.3	4.29	55.1
Difference	−3.6	1.10	−3.4	0.81	−20.4

TABLE I—*Continued*

	Quoted spread (cents)	Quoted spread (%)	Effective spread (cents)	Effective spread (%)	Trading volume
Panel C: Averages across firms, based on market-maker quotation behavior					
555 firms that use odd-eighths when $p > 10$, but avoid odd-sixteenths when $p < 10$ (Group 1A)					
Over \$10	41.3	3.41	32.6	2.71	90.6
Under \$10	38.6	4.74	30.2	3.71	65.0
Difference	−2.7	1.32	−2.4	1.00	−25.6
50 firms that use odd-eighths when $p > 10$, and use odd-sixteenths when $p < 10$ (Group 1B)					
Over \$10	26.1	2.19	20.9	1.75	275.8
Under \$10	22.0	4.26	17.1	3.41	178.6
Difference	−4.1	2.07	−3.8	1.67	−97.2
97 firms that avoid odd-eighths when $p > 10$, and avoid odd-eighths when $p < \$10$ (Group 2A)					
Over \$10	84.0	6.78	71.3	6.78	15.9
Under \$10	75.6	8.44	63.3	7.08	14.5
Difference	−8.4	1.67	−8.0	1.29	−1.3
63 firms that avoid odd-eighths when $p > 10$, but use odd-eighths when $p > 10$ (Group 2B)					
Over \$10	68.3	5.68	54.4	4.53	25.7
Under \$10	59.5	7.44	47.1	5.85	29.4
Difference	−8.7	1.76	−7.3	1.32	3.6

Note. The quoted spread for each firm or event is the time-weighted average. The effective spread for each firm or event is the simple mean across trades of the absolute difference between the trade price and the bid–ask midpoint. Reported are simple means computed across firms or events. Trading volumes are in thousands of shares per day.

the tick size change and reveal little evidence that spreads react to tick size changes with a time lag.

Evaluating the effects of tick size changes by use of data from the Nasdaq stock market is made more complicated by the empirical regularity, first documented by

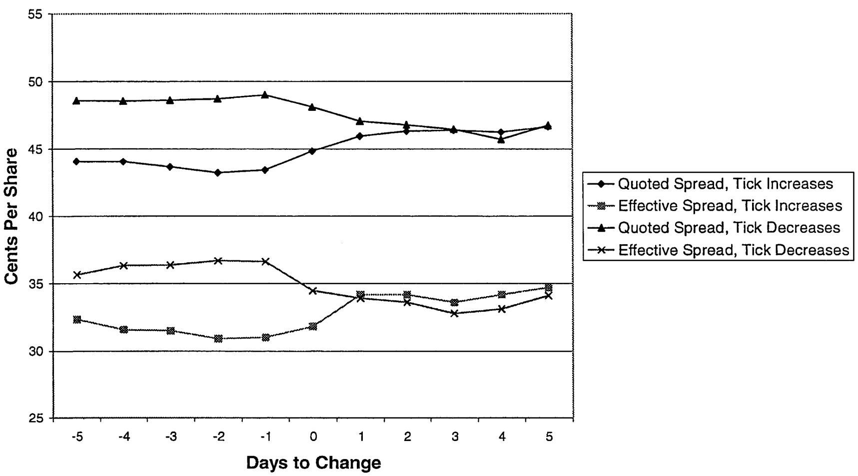

FIG. 1. Average bid–ask spreads around tick size changes with durations of at least 5 days.

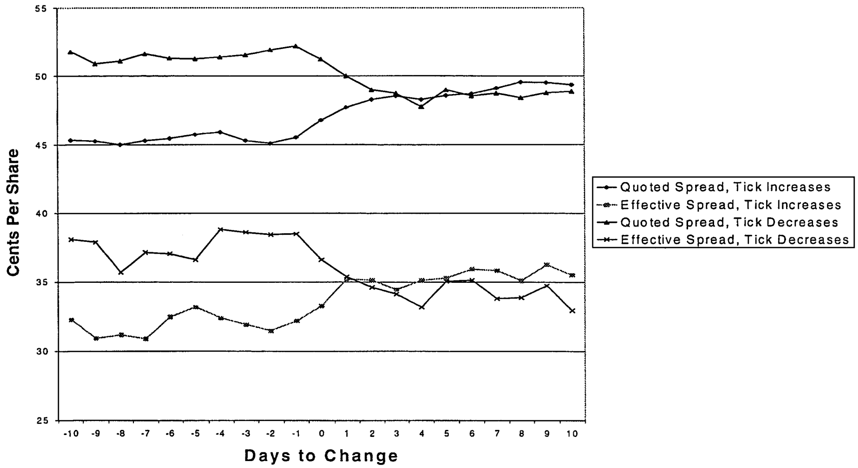

FIG. 2. Average bid–ask spreads around tick size changes with durations of at least 10 days.

Christie and Schultz (1994), that some Nasdaq market makers refrain from using odd multiples of the minimum tick in their quotations. Christie and Schultz focus on higher-priced stocks and document the systematic avoidance of odd-eighth quotations. In the present study, I find that Nasdaq market makers make relatively little use of odd sixteenth or odd thirty-second fractions for stocks priced below \$10. In fact, market makers for only 270 of the 765 sample firms ever post a quotation that uses a fractional price finer than 1/8 dollar, and only 70 firms ever post a quotation that is an odd multiple of 1/32 dollar.

To identify the effect of changes in tick sizes it may be useful to accommodate the tendency for market makers to avoid odd-tick quotations. Separation of the sample

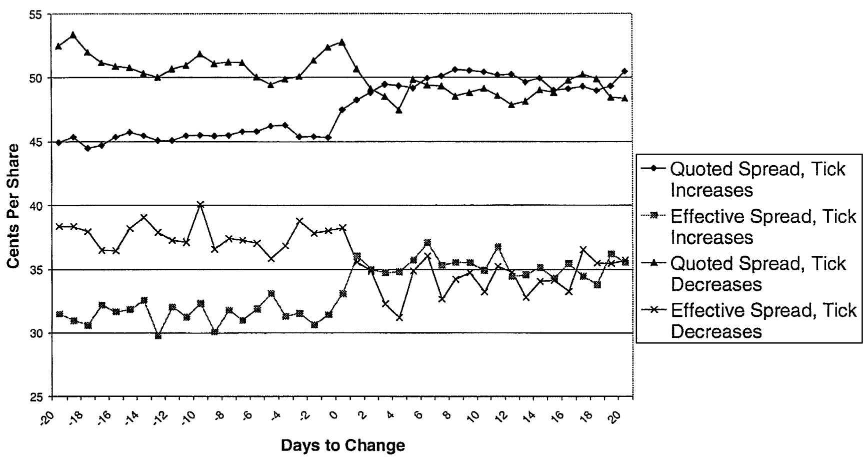

FIG. 3. Average bid–ask spreads around tick size changes with durations of at least 20 days.

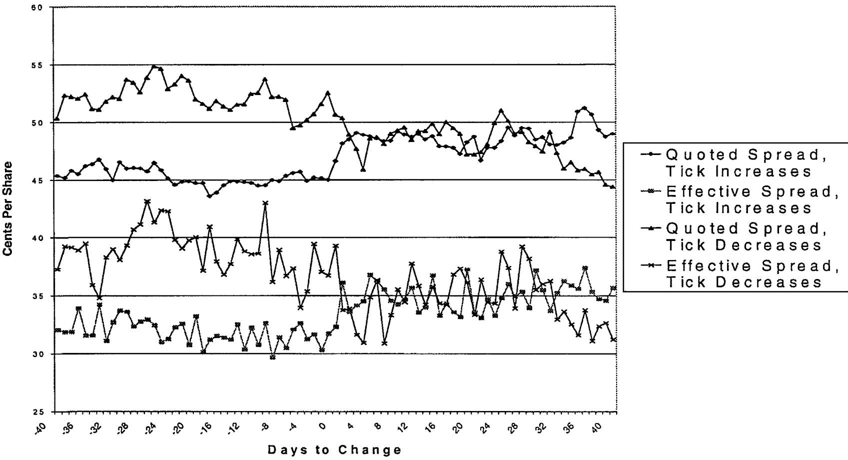

FIG. 4. Average bid–ask spreads around tick size changes with durations of at least 40 days.

based on quotation rounding frequency is also useful for testing some implications of the model presented by Kandel and Marx (1997). Besides predicting that the equilibrium spread will decline with a smaller tick size, their model predicts that market makers who avoid odd-eighth quotations when there is a one-eighth dollar tick size will begin to use odd-eighth and odd-sixteenth quotations when there is a 1/32 dollar tick size.

Panel C of Table I reports on spreads for subsamples based on market-maker quotation behavior. Firms are first categorized based on whether market makers use odd-eighth fractions for at least 5% of quotations when priced over $10.[8] Firms whose market makers do use odd-eighth fractions when priced over $10 are hereafter referred to as Group 1, while firms whose market makers do not make use of odd-eighth quotations (for at least 5% of observations) are referred to as Group 2.

I then further divide these groups based on quotation behavior during the portion of the event period when they trade under $10. Those Group 1 firms whose market makers do not make use of odd-sixteenth quotations (for at least 5% of observations) when trading below $10 are referred to as Group 1A, while Group 1 firms whose market makers do make use of odd-sixteenth quotations below $10 are referred to as Group 1B. Group 1A firms do not avoid odd-eighths when priced over $10, but fail to use odd-sixteenths when priced under $10. A likely explanation is that the equilibrium spread is 1/8 dollar or wider for these firms, implying that the one-eighth tick size does not impose a binding constraint.

[8] As Christie and Schultz (1994) note, firms whose market makers avoid odd-eighth quotations tend to do so all, or very nearly all, of the time. In contrast, market makers that use odd-eighth quotations tend to do so frequently—close to 50% of the time on average. As a consequence, the number of firms assigned to each group is relatively insensitive to variation in the 5% cutoff.

Group 2 firms are subdivided similarly. In contrast to the predictions of the Kandel and Marx (1997) model, none of the Group 2 firms make substantial use of odd-sixteenths when the tick size is 1/32 of a dollar. However, some Group 2 firms do make use of odd-eighths below \$10. Those Group 2 firms whose market makers do not make use of odd-eighth quotations (for at least 5% of observations) when trading below \$10 are referred to as Group 2A, while Group 2 firms whose market makers do use odd-eighth quotations below \$10 are referred to as Group 2B.

The most notable result on Panel C of Table I is that spread reductions are much larger for firms that avoid odd-eighth quotes when priced over \$10. Reductions in quoted spreads average 8.4 and 8.7 cents per share for Group 2A and 2B firms, compared to reductions of 2.7 and 4.1 cents in Groups 1A and 1B, respectively. Moreover, stocks in Groups 2A and 2B have spreads when priced over \$10 that average 84.0 and 68.3 cents, respectively. Since these spreads are four to five times the 1/8 dollar tick size in effect over \$10, it cannot be argued that the tick size directly constrained the spread. In contrast, spreads for Group 1B stocks average 22.0 cents when priced over \$10, indicating that the 1/8 dollar tick size may create a binding constraint at times.

With the exception of estimates obtained from very short (one and five day) horizon events, the point estimates obtained here indicate spread reductions with the smaller tick size ranging from 3 to 6 cents per share. These estimates are similar or larger in magnitude to those reported in the wake of market-wide tick size reductions. Goldstein and Kavajecz (2000), Ricker (1998), and Jones and Lipson (2000) each examine the June 1997 NYSE tick size reduction and report that quoted spreads decline by 2.8 to 3.0 cents per share. Ronen and Weaver (1998) examine the May 1997 AMEX tick size reduction and report a decrease in spreads of 1.9 cents per share. Jones and Lipson also consider the June 1997 Nasdaq tick size reduction and report that spreads are decreased by an average of 2.7 cents per share. It should be noted, though, that these studies focus on three events that are closely clustered in time. The results presented here are obtained with a substantially larger effective sample size and therefore provide a greater degree of confidence regarding the effect of tick size changes on spreads. However, the tick size changes observed here are, by construction, accompanied by share price changes, which may themselves reflect new information and unusual trading activity. The effect of the tick size change after allowing for contemporaneous changes in share price and trading activity is assessed in Sections 3B and 3C.

The remainder of this paper reports results for three of the subsamples identified on Table I: the set of 176 firms that experience only a single tick size change, the set of 796 events with durations of at least 10 days, and the set of 252 events with durations of at least 40 days. These subsamples reflect events with a greater degree of permanence and should provide more powerful tests for the effect of tick size changes.

B. Statistical Significance and Tick Increases versus Tick Decreases

Each mean that is reported in Table I is obtained from a pooled cross-sectional (across firms or events) and time series (across days) sample. To assess statistical significance and to compare tick-increasing events to tick-decreasing events in this context, I adopt a fixed-effects estimation procedure. (See, for example, Chapter 16 of Judge *et al.* (1982)). Letting S_{it} denote the bid–ask spread observed on day t for firm or crossing event i, the effect of the tick size change is ascertained by estimating the regression equation:

$$S_{it} = \sum_{i=1}^{N} \alpha_i + \mathrm{D}_1\mathrm{UNDERINCR}_{it} + \mathrm{D}_2\mathrm{UNDERDECR}_{it} + \varepsilon_{it}, \qquad (1)$$

where the α_i represent event-specific intercepts for the N events or firms, $\mathrm{UNDERINCR}_{it}$ is an indicator variable that equals one for days when the share price is under \$10 and the event is a tick size increase, and zero otherwise, and $\mathrm{UNDERDECR}_{it}$ is an indicator variable that equals one for days when the share price is under \$10 and the event is a tick size decrease, and zero otherwise. The event-specific intercepts accommodate the fact that the daily spread observations for each event pertain to the same firm and are therefore not independent. The estimated coefficients on the indicator variables represent the average shift in spreads with the smaller tick size, for each type of event, and the regression framework allows for standard hypothesis testing.

The results of estimating Eq. (1) are reported in Table II and indicate that the reductions in quoted and effective bid–ask spreads with the smaller tick size are very significant in a statistical sense. t statistics on the indicator variables range from -8.1 to -21.2 for quoted spreads and from -9.6 to -17.0 for effective spreads.

It may take time for market participants to learn about and begin to use the increased flexibility afforded by a finer tick size. If so, the short run equilibrium may be relatively unaffected by a tick size reduction. In contrast, a tick size increase immediately constrains market makers to using a coarser pricing grid, implying that tick size increases are potentially more informative regarding the effect of the tick size on market quality.

The evidence reported in Table II provides little if any support for the reasoning that tick size increases have differential effects as compared to tick size decreases. Point estimates for tick decreases are generally slightly larger in absolute magnitude than for tick increases, but the differential is in most instances not statistically significant.

C. The Role of Variation in Share Price and Trading Volume

As noted in the introduction, a disadvantage of a research design that focuses on tick size changes as a function of stock price is that the tick size change is necessarily accompanied by a share price change. Bid–ask spreads are generally

TABLE II
Changes in Quoted and Effective Spreads around Tick Size Changes and the Effect of Contemporaneous Changes in Share Price and Trading Volume

	Quoted spread				Effective spread			
	Coefficient	t statistic	Coefficient	t statistic	Coefficient	t statistic	Coefficient	t statistic
Panel A: 176 firms whose stock price passed through $10 once during 1995								
Indicator variables								
Tick increase	−5.08	−21.23	−3.64	−13.33	−4.38	−17.01	−3.39	−11.51
Tick decrease	−5.84	−13.92	−3.62	−8.03	−5.48	−12.13	−3.93	−8.07
1/price			−29.09	−12.72			−20.28	−8.23
Volume			−5.63	−10.36			−4.39	−7.49
Test equal (p-value)	(0.117)		(0.967)		(0.034)		(0.307)	
Regression adjusted R-square	.024		.034		.016		.021	
Panel B: 796 events where share price remained over or under $10 for at least 10 trading days								
Indicator variables								
Tick increase	−3.40	−11.92	−2.65	−7.86	−3.19	−9.92	−2.49	−6.53
Tick decrease	−2.73	−8.13	−2.07	−5.35	−3.62	−9.58	−2.43	−5.25
1/price			−55.89	−5.28			−50.18	−4.20
Volume			−3.69	−5.83			−2.71	−3.79
Test equal (p-value)	(0.125)		(0.004)		(0.385)		(0.902)	
Regression adjusted R-square	.021		.027		.021		.023	

Panel C: 252 events where share price remained over or under $10 for at least 40 trading days

Indicator variables								
Tick increase	−3.42	−14.61	−2.25	−7.46	−3.04	−11.37	−2.13	−6.18
Tick decrease	−4.05	−12.24	−2.18	−5.33	−4.19	−11.10	−2.65	−5.67
1/price			−44.71	−7.28			−36.28	−5.17
Volume			−5.23	−7.55			−5.31	−6.69
Test equal (p-value)	(0.124)		0.864		(0.013)		0.268	
Regression adjusted R-square	.029		.037		.019		.026	

Note. The coefficients reported are obtained in pooled time-series cross-sectional regressions, using a fixed-effects approach. The dependent variable is the quoted or effective spread for firm i on day t. The "tick increase" indicator equals one if the event is a tick size increase and the share price is below $10, and zero otherwise. The "tick decrease" indicator equals one if the event is a tick size decrease and the share price is below $10, and zero otherwise. Each regression includes a set of event-specific intercepts, coefficients of which are not reported. The estimated coefficients on the indicator variables measure the change in the average spread with the smaller tick size, *ceteris paribus*. "Test equal" denotes the probability-value obtained in a F test of the hypothesis that the estimated coefficients on the two indicator variables are equal. "1/price" and "volume" denote the inverse of the daily closing bid–ask midpoint and daily trading activity in thousands of shares, respectively.

correlated with share prices (e.g., Harris (1994) and Bessembinder (1997)). In addition, since a price movement is required to change the tick size, the event may be accompanied by unusual trading activity and information flows.

To evaluate whether the tick size change has an effect on average spreads that is independent of the changes in trading activity and average share price, I augment the fixed-effects regression model to include day t trading volume for firm i, denoted V_{it}, as well as the inverse of the day t share price for firm i, denoted $1/P_{it}$:[9]

$$S_{it} = \sum_{i=1}^{N} \alpha_i + \mathrm{D}_1\mathrm{UNDERINCR}_{it} + \mathrm{D}_2\mathrm{UNDERDECR}_{it} + \mathrm{D}_3 V_{it} + \mathrm{D}_4(1/P_{it}) + \varepsilon_{it}. \quad (2)$$

The results of estimating (2) are reported in Table II. Consistent with prior studies (e.g., Benston and Hagerman (1978) and Harris 1994)), a significant negative relation is observed between bid–ask spreads and trading volume. Also consistent with prior evidence, the estimated coefficient on the inverse of share price is negative and significant, indicating that bid–ask spreads on average increase with share price. Coefficient estimates on the indicator variables obtained when estimating (2) are smaller (in absolute magnitude) than those obtained when estimating (1), indicating that variation in share prices and trading volumes provide a partial explanation for the change in average spreads after tick size changes. However, the estimated coefficients on the indicator variables in (2) remain negative and statistically significant. The point estimates indicate that the tick size change has an independent effect on both quoted and effective spreads of between 2.1 and 3.9 cents per share.

4. CROSS-SECTIONAL VARIATION IN SPREAD DECLINES

A. *Spread Decreases by Quotation Rounding Group*

To assess whether the reduction in spreads with the smaller tick size is related to the degree to which market makers make use of the pricing grid that is available, I estimate the following specifications:

$$S_{it} = \sum_{i=1}^{N} \alpha_i + \mathrm{D}_1\mathrm{GROUP1A}_{it} + \mathrm{D}_2\mathrm{GROUP1B}_{it} + \mathrm{D}_3\mathrm{GROUP2A}_{it} + \mathrm{D}_4\mathrm{GROUP2B}_{it} + \varepsilon_{it} \quad (3)$$

[9] The use of the inverse of share price is based on the evidence reported by Harris (1994) indicating that the empirical relation between spreads and share price is best explained as an inverse rather than a linear function.

$$S_{it} = \sum_{i=1}^{N} \alpha_i + \mathrm{D_1GROUP1A}_{it} + \mathrm{D_2GROUP1B}_{it} + \mathrm{D_3GROUP2A}_{it} + \mathrm{D_4GROUP2B}_{it} + \mathrm{D}_5 V_{it} + \mathrm{D}_6(1/P_{it}) + \varepsilon_{it}, \quad (4)$$

where $\mathrm{GROUP1A}_{it}$ is an indicator variable that equals 1 if firm i's day t share price is under \$10 and firm i is included in Group 1A; $\mathrm{GROUP2A}_{it}$ is an indicator variable that equals 1 if firm i's day t share price is under \$10 and firm i is included in Group 2A, etc. Coefficient estimates on these indicator variables measure the average change in spreads when prices are under \$10, for each group. Specification (4) estimates the effect of the tick size change, after controlling for contemporaneous volume and share price changes.

The most striking result that can be observed in Table III is that the reduction in spreads associated with the smaller tick size is always greater for stocks whose market makers avoid odd-eighth quotes when priced over \$10 (Group 2 stocks). The hypothesis that the change in spreads is equal across groups can be rejected (p-value < 0.001) for each subsample. The differentials across groups are typically large, with spread reductions for Group 2 firms typically more than twice as large as for Group 1.

Observing the largest spread reductions for Group 2 firms is somewhat surprising when viewed in terms of the most readily apparent explanation for a relation between tick sizes and spread widths—that the tick size constrains the spread to be at least one tick. As noted in Section 2, spreads for Group 2 firms are on average between 60 and 80 cents per share, implying that a one-eighth dollar tick size does not directly constrain spread widths. The reduction in trade execution costs for Group 2 firms is, however, consistent with implications of models presented by Kandel and Marx (1997) and Dutta and Madhavan (1997). Their models imply that price discreteness can be used to support equilibrium spreads that exceed marginal trade-processing costs and that equilibrium spreads will decrease with the tick size.

The evidence is not uniformly supportive of these models, however. Kandel and Marx (1997) predict that the reduction in spreads with the smaller tick size should be observed when market makers begin to use odd-sixteenths in their quotations. In this sample only a minority of Group 2 firms actually make use of odd-sixteenths when the tick size decreases, and spread reductions for those firms (Group 2B) are not uniformly greater than for stocks whose market makers continue to avoid odd-eighths (Group 2A). The strongest support for their model is in the subsample of stocks whose share priced passed through \$10 only once. In this sample spread reductions with the smaller tick size are twice as large for Group 2B stocks. This indicates a greater degree of support for the Kandel and Marx model for more permanent tick size changes.

Stocks in Group 1B are those for which market makers actually make use of odd-sixteenths when the tick size is reduced. Spread reductions for stocks in Group 1B are slightly larger than for those in Group 1A, consistent with the reasoning

TABLE III

Changes in Average Quoted and Effective Spreads around Tick Size Changes and the Effect of Contemporaneous Changes in Share Price and Trading Volume, for Four Groups of Firms

	Quoted spread				Effective spread			
	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic
Panel A: 176 firms whose stock price passed through $10 once during 1995								
Indicator variables								
Group 1A (116 firms)	−4.42	−17.87	−2.89	−10.24	−3.68	−13.81	−2.58	−8.45
Group 1B (12 firms)	−4.77	−5.68	−1.12	−1.25	−3.82	−4.23	−1.21	−1.27
Group 2A (31 firms)	−5.27	−9.85	−4.08	−7.51	−6.08	−10.56	−5.22	−8.92
Group 2B (17 firms)	−12.76	−17.86	−10.54	−13.38	−10.78	−14.01	−9.17	−11.59
1/price			−29.56	−12.62			−21.40	−8.47
Volume			−5.39	−9.95			−4.20	−7.18
Test equal (p-value)	(0.000)		(0.000)		(0.000)		(0.000)	
Regression adjusted R-square	.027		.038		.019		.022	
Panel B: 796 events where the stock price remained over or under $10 for 10 days								
Indicator variables								
Group 1A (568 events)	−1.31	−5.17	−0.20	−0.64	−1.73	−6.01	−0.66	−1.85
Group 1B (42 events)	−2.17	−2.32	0.67	0.61	−1.91	−1.80	0.79	0.67
Group 2A (114 events)	−12.07	−21.21	−11.03	−18.64	−10.62	−16.49	−9.64	−14.37
Group 2B (72 events)	−3.69	−5.14	−2.20	−2.92	−5.65	−6.97	−4.24	−4.98
1/price			−67.16	−6.18			−63.56	−5.16
Volume			−3.18	−5.11			−2.43	−3.45
Test equal (p-value)	(0.000)		(0.000)		(0.000)		(0.000)	
Regression adjusted R-square	.049		.056		.035		.040	

Panel C: 252 events where the stock price remained over or under \$10 for 40 days

Indicator variables								
Group 1A (116 events)	−2.06	−9.11	0.02	0.05	−1.86	−7.21	−0.04	−0.12
Group 1B (9 events	−3.36	−3.35	−0.98	−0.93	−3.11	−2.71	−1.14	−0.94
Group 2A (43 events)	−10.00	−21.78	−8.68	−18.20	−9.96	−18.98	−8.79	−16.12
Group 2B (22 events)	−3.93	−6.13	−1.62	−2.39	−3.32	−4.53	−1.27	−1.64
1/price			−61.54	−9.98			−54.48	−7.12
Volume			−5.02	−7.30			−5.21	−6.63
Test equal (p-value)	(0.000)		(0.000)		(0.000)		(0.000)	
Regression adjusted R-square	.046		.057		.034		.042	

Note. Group 1A (1B) consists of firms whose market makers made use of odd-eighth fractions for at least 5% of quotations when priced over \$10 and made use of odd-sixteenth fractions for less (more) than 5% of quotations when priced below \$10. Group 2A (2B) consists of firms whose market makers made use of odd-eighth fractions for less than 5% of quotations when priced over \$10 and made use of odd-eighth fractions for less (more) than 5% of quotations when priced below \$10. The coefficients reported are obtained in pooled time-series cross-sectional regressions, using a fixed-effects approach. The dependent variable is the quoted or effective spread for firm i on day t. Each regression includes a set of event-specific intercepts, coefficients of which are not reported. Coefficients of indicator variables measure the change in the average spread with the smaller tick size, *ceteris paribus*. "Test equal" denotes the probability value obtained in a F test of the hypothesis that the estimated coefficients on the four indicator variables are equal. "1/price" and "volume" denote the inverse of the daily closing bid–ask midpoint and daily trading activity in thousands of shares, respectively.

that the tick decrease eliminated a binding constraint on spread widths for the few sample firms in this group.

B. Spread Changes and Firm Characteristics

It has repeatedly been asserted that tick size reductions will have an adverse impact on liquidity provision for smaller and less-liquid stocks.[10] I investigate this assertion for the present sample of Nasdaq stocks by estimating a set of cross-sectional regressions where the dependent variable for each event is the percentage change (observation below $10 less paired observation above $10, divided by observation above $10) in spreads. The explanatory variables include the beginning-of-sample market capitalization of the stock involved and the average trading activity during the pre-event period. Additionally, I include measures of the change (observation below $10 less paired observation above $10) in the percentage of quotes rounded to even-eighths and the percentage of quotes using odd-sixteenths below $10.

The results of this analysis are reported in Table IV. Coefficient estimates on market capitalization and trading activity variables are uniformly insignificant, with most *t* statistics less than 1.0 in absolute magnitude. Thus this analysis provides no evidence that trading costs for smaller or less actively traded securities are adversely affected by a smaller tick size.

In fact, the only variables with significant explanatory power for cross-sectional variation in the spread change are those that measure the frequency with which market makers use odd increments of the pricing grid. The positive and significant coefficient estimates on the "change in even-eighth quotes" variable indicate larger reductions in spreads for firms whose market makers make larger reductions in the frequency of quotation rounding. The negative (though not uniformly significant) coefficient estimates on the "odd-sixteenth usage" variable indicates larger spread reductions for firms whose market makers use odd-sixteenths more frequently when prices are under $10. These findings reaffirm the empirical regularity (Christie and Schultz, 1994; Bessembinder, 1997) that trade execution costs on the Nasdaq market are related to the degree to which market makers use or avoid odd-tick quotations.

5. LIQUIDITY PROVISION AND THE TICK SIZE

Reductions in tick size could lead to reductions in liquidity supply. Harris (1994) predicts that quote sizes will be reduced, and this implication has been supported

[10] See, for example, "Will New Rules Affect Smallest Issues Liquidity?," *Wall Street Journal*, June 9, 1997, p. C1 and "Stock Markets Get the Point by July 2000," *Wall Street Journal*, Sept. 23, 1999, p. C1.

in several studies.[11] Decreased liquidity could be manifest in the form of more volatile prices. However, increased volatility might also reflect changes in the rate of information flow. As a consequence, I also use intraday variance ratios to evaluate whether price changes are reversed on average. Such reversals, if they exist, would indicate that order flows or other shocks push prices beyond their longer term equilibrium and would be indicative of a lack of liquidity.

Volatility is measured based on standard deviations of continuously compounded intraday (10 a.m. to 4 p.m.) and daily (4 p.m. to 4 p.m.) returns. To avoid the volatility-increasing properties of *bid–ask bounce*, volatility is measured using returns that are computed from the midpoints of the bid and ask quotations in effect at the designated times. Separate volatility measures are computed for days with closing quote midpoints over and under $10.

To test for intraday price reversals, I construct intraday variance ratios. For each firm, variance ratios are computed as six times the variance of hourly quote midpoint returns divided by the variance of six-hour (10 a.m. to 4 p.m.) quote midpoint returns. If quote midpoints follow random walks, implying that price changes are permanent on average, then return variances variance ratios will not systematically deviate from one. (See, for example, Poterba and Summers (1986)). If, in contrast, intraday prices changes are systematically reversed, indicating a lack of liquidity, then the variance of six-hour returns will be dampened, and variance ratios will tend to be greater than one.

Empirical results regarding volatility and the tick size are reported in Table V. A clear pattern can be observed—volatility is higher after both tick size increasing and tick size decreasing events. A likely explanation is that the passage of a stock price through $10 is associated with simultaneous increases in information flow. When tick size increasing and decreasing events are pooled, median volatility is lower with the smaller tick size. For example, for 10-day horizon events the cross-sectional median volatility of daily (intraday) returns is 1.91% (1.59%) with the smaller tick size compared to 2.01% (1.81%) with the larger tick size. Formal binomial tests generally reject the hypothesis that the proportion of events with lower volatility equals 50%, indicating that the decline in volatility with the smaller tick size is nonrandom.

The possibility that rates of information flow may change in the wake of tick size changes implies that the evaluation of intraday variance ratios is more likely to provide a cleaner test of whether liquidity provision is altered by the tick size changes than evaluation of volatility per se. The cross-sectional median variance ratios reported in Table V are typically slightly below 1.0, indicating the presence of mild intraday continuations rather than reversals of prices.

[11] See the review article by Harris (1997). Quotation sizes for Nasdaq firms reported in the TAQ database during 1995 virtually always indicate the NASD-required minimum size (which was then 1000 shares) and do not indicate the number of market-making firms at the inside quote. These limitations preclude any meaningful measurement of liquidity provision by analysis of Nasdaq quotation sizes.

TABLE IV
Cross-Sectional Analysis of Changes in Average Quoted and Effective Bid–Ask Spreads around Tick Size Changes

	Quoted spreads				Effective spreads			
	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic
Panel A: 176 firms whose stock price passed through $10 once during 1995								
Intercept	−0.08	−2.65	−0.07	−2.47	−0.10	−3.52	−0.09	−3.41
Market capitalization	−0.08	−0.21	−0.23	−0.74	0.03	0.11	−0.12	−0.36
Trading volume	−0.05	−0.20	0.21	0.81	−0.16	−0.64	0.06	0.25
Change in even-eighth quotes			0.37	3.36			0.39	3.56
Change in odd-sixteenth quotes			−0.95	−2.25			−0.75	−1.80
Regression adjusted R-Square	.001		.144		.004		.141	
Panel B: 796 events where the stock price remained over or under $10 for ten trading days								
Intercept	−0.01	−0.44	−0.01	−0.57	−0.03	−1.68	−0.03	−1.83
Market capitalization	−0.08	−0.61	−0.04	−0.29	−0.08	−0.59	−0.04	−0.28
Trading volume	−0.06	−0.69	−0.01	−0.14	−0.10	−1.04	−0.05	−0.56
Change in even-eighth quotes			0.25	4.46			0.25	4.20
Change in odd-sixteenth quotes			−0.21	−0.81			−0.16	−0.58
Regression adjusted R-square	.002		.030		.003		.028	

Panel C: 252 events where share price remained over or under \$10 for at least 40 trading days								
Intercept	−0.03	−1.26	−0.02	−1.16	−0.06	−2.48	−0.05	−2.23
Market capitalization	−0.26	−1.22	−0.29	−1.41	−0.16	−0.75	−0.19	−0.89
Trading volume	−0.01	−0.06	0.15	0.84	−0.05	−0.28	0.10	0.58
Change in even-eighth quotes			0.34	4.21			0.34	4.14
Change in odd-sixteenth quotes			−0.92	−2.49			−0.87	−2.31
Regression adjusted R-square	.008		.103		.004		.094	

Note. The coefficients reported are obtained in cross-sectional regressions where the dependent variable is the proportional change (observation when prices are below \$10 less the matching observation when prices are over \$10 divided by observation when prices are over \$10) in the average time weighted spread around tick size changes. The explanatory variables include the stock's beginning-of-sample market capitalization in \$ billion and average trading volume prior to the tick size change in millions of shares per day. "Change in even eighth quotes" is the percentage of quotes below \$10 that use even-eighths less the percentage of quotes above \$10 that use even-eighths. "Change in odd–sixteenth quotes" is the percentage of quotes below \$10 that use odd-sixteenths. t statistics are based on White (1980) heteroskedasticity-consistent standard errors.

TABLE V
Average Return Volatility before and after Tick Size Changes

	All events				Tick size increasing events				Tick size decreasing events			
	Above $10	Below $10	% with increase	Binomial *p*-value	Above $10	Below $10	% with increase	Binomial *p*-value	Above $10	Below $10	% with increase	Binomial *p*-value
Panel A: 176 firms whose share price passed through $10 once during 1995												
Daily standard deviation	2.79	2.40	37.85	0.002	2.94	1.93	18.75	0.000	2.38	4.80	87.75	0.000
Intraday standard deviation	2.16	2.05	40.11	0.010	2.25	1.57	24.22	0.000	1.86	2.96	81.63	0.000
Intraday variance ratio	0.88	0.88	49.15	0.881	0.88	0.88	46.88	0.536	0.85	0.89	55.10	0.392
Panel B: 796 events where share price remained over (under) $10 for at least 10 trading days												
Daily standard deviation	2.01	1.91	45.60	0.014	2.37	1.78	34.60	0.000	1.65	2.24	60.80	0.000
Intraday standard deviation	1.81	1.59	46.11	0.031	2.00	1.48	37.00	0.000	1.48	1.81	58.70	0.001
Intraday variance ratio	0.93	0.96	49.25	0.700	0.91	0.95	47.40	0.285	0.98	0.96	51.80	0.477
Panel C: 252 events where share price remained over (under) $10 for at least 40 trading days												
Daily standard deviation	2.30	2.14	41.67	0.010	2.46	1.83	26.20	0.000	1.99	2.83	72.60	0.000
Intraday standard deviation	1.86	1.86	41.67	0.010	2.05	1.52	27.40	0.000	1.64	2.43	70.20	0.000
Intraday variance ratio	0.86	0.88	51.19	0.660	0.86	0.87	54.20	0.248	0.93	0.85	45.20	0.445

Note. The standard deviation of daily returns is computed based on closing quote midpoints. The standard deviation of intraday returns is based on quote midpoints observed at 10 a.m. and 4 p.m. The intraday variance ratio is the ratio of six times the variance of hourly quote midpoint returns to the variance of six-hour (10 a.m. to 4 p.m) returns. Reported are cross-sectional medians for each volatility measure. The column labeled "% with increase" reports the percentage of events where the volatility measure is larger when prices are below $10. The binomial *p*-value pertains to the hypothesis that the probability of an increase in the volatility measure equals 0.5.

Median variance ratios are generally quite similar before and after the tick size change. Consider, for example, the subsample of 176 stocks whose share price passed through \$10 only one time, where the median variance ratio is 0.88 for both tick sizes. The hypothesis that the percentage of events displaying increased variance ratios equals 50 is not rejected for any of the subsamples, for tick size increasing or decreasing events. These results are consistent with the hypothesis that the tendency for price changes to be subsequently continued or reversed is unaffected by the tick size change.

Median volatility is slightly lower with the smaller tick size, and there is no evidence of changes in the extent to which price changes are subsequently reversed. This analysis therefore provides no evidence of a reduction in liquidity with the smaller tick size for the present sample. However, this result may be sample-specific. The companies included in this study are relatively small and, by construction, have relatively low share prices in the vicinity of \$10. The economic costs of market making are likely to be greater for smaller companies, and the lower share prices imply a larger tick size on a percentage basis. As a consequence, the tick size may be less important in explaining liquidity provision for the present sample as compared to higher-priced stocks or stocks of larger firms. Harris (1996) and Goldstein and Kavajecz (1999) have documented reductions in liquidity supply with a smaller tick size for samples that include stocks of larger companies with higher share prices.

6. CONCLUSIONS

This study examines changes in trade execution costs and market quality for a set of 765 Nasdaq-listed firms whose tick size changed as their share prices passed through \$10 during calendar year 1995. This analysis allows for a substantially larger effective sample size as compared to before-versus-after studies of market-wide tick size reductions, and allows for separate examination of tick size increases and decreases. The empirical results indicate that bid–ask spreads are decreased by three to five cents per share with the smaller tick size and provide no evidence of a reduction in liquidity.

The most intriguing empirical result obtained in this study is the finding of large trading cost reductions with the smaller tick size for firms that avoid odd-eighth quotations when the tick size is 1/8 dollar. These reductions occur even though the average quoted spread for these firms is more than four times the tick size, indicating the absence of a binding constraint. These results provide support for models such as Dutta and Madhavan (1997) and Kandel and Marx (1997), which imply that the equilibrium spread on dealer markets can depend on the tick size, even when the tick size does not directly constrain spread widths.

Harris (1997) suggests that an important role of the tick size on markets that enforce time precedence rules (which require orders to be matched with the earliest displayed quote at a given price) is that it determines the cost of obtaining order precedence by improving on the existing quote. The Nasdaq market, like other dealer markets such as the London Stock Exchange and the U.S. Treasury Security markets, does not enforce time precedence rules. As a consequence it is somewhat surprising that the reductions in bid–ask spreads with the smaller tick size documented here are similar in magnitude to those reported in before-versus-after comparisons of tick size reductions on markets that enforce time priority, such as the NYSE, AMEX, and Toronto exchanges. These results highlight that the relation between tick size and trade execution costs is more complex than the imposition of a simple constraint on minimum spread widths and indicate that the tick size may have more impact on trading costs in dealer markets than has previously been recognized.

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