SIXTEENTHS: DIRECT EVIDENCE ON INSTITUTIONAL TRADING COSTS

Charles M. Jones
Graduate School of Business
Columbia University

and

Marc L. Lipson
Terry College of Business
University of Georgia
and
New York Stock Exchange

This draft: July 1998

We thank Robert Battalio, Hank Bessembinder, Shane Corwin, Larry Glosten, Michael Goldstein, Tim McCormick, Harold Mulherin, and George Sofianos for comments. We are grateful to the Plexus Group for providing the data set, and we especially thank Wayne Wagner and Larry Cuneo of Plexus for their help with the data and their comments.

ABSTRACT

In June 1997, the Nasdaq stock market and the New York Stock Exchange (NYSE) each lowered its minimum price increment on most stocks from eighths to sixteenths. Like other researchers investigating similar events, we find that quoted spreads and effective spreads decline on both markets at the introduction of sixteenths. However, spreads do not necessarily measure the cost of trading, particularly for market participants who execute larger orders over time. In this paper, we use a sample of institutional trades provided by the Plexus Group to directly measure the effect of the tick size reduction on trading costs. For these institutions, the cost of small NYSE and Nasdaq trades (less than 10,000 shares) is little changed by the advent of sixteenths. However, NYSE trades of at least 10,000 shares are more expensive to execute when prices are quoted in sixteenths, and the cost differential increases with order size. Overall, for the institutions in this sample, the move to sixteenths has resulted in *increased* trading costs. These findings emphasize that spreads are not a sufficient statistic for measuring market quality; they also suggest that smaller price increments may not be pareto-improving.

SIXTEENTHS: DIRECT EVIDENCE ON INSTITUTIONAL TRADING COSTS

1. Introduction

On June 2, 1997, the Nasdaq stock market lowered its minimum price increment on most stocks from eighths of a dollar to sixteenths. The New York Stock Exchange (NYSE) followed suit on June 24, 1997. This change to sixteenths is perhaps an interim step in a move toward decimalization of prices. However, there is considerable debate among regulators, practitioners, and academics about the optimal minimum price increment. In this paper, we use a proprietary set of institutional trades to gauge the effect of a reduction in tick size on realized costs of trading.

In an effort to inform the current debate, a number of researchers have looked at the effects of tick size reductions on traditional measures of trading costs. For example, Bacidore (1997), Porter and Weaver (1997), and Ahn, Cao, and Choe (1998), among others, examine the effects of the recent reduction in tick size on the Toronto Stock Exchange. Ronen and Weaver (1998) analyze the May 7, 1997 changeover to sixteenths on the American Stock Exchange (AMEX). Goldstein and Kavajecz (1998) examine the limit order book around the adoption of sixteenths by the NYSE. Harris (1997) provides a comprehensive summary of theoretical and empirical issues associated with decimalization and changes in tick size more generally. In all of these empirical studies, both quoted and effective bid-ask spreads generally decline. Such findings are generally interpreted as evidence of a decline in trading costs, and thus as an improvement in market quality (see Ricker, 1998, for example).

We obtain similar results on quoted and effective spreads for the NYSE and Nasdaq moves to sixteenths. However, spreads do not necessarily measure the cost of trading, particularly for market participants who execute larger orders over time. These participants are

mostly institutions, and they care a great deal about the ease and cost of transacting large quantities of stock. For these participants, the effective spread for trading 100,000 shares of IBM in a single block may not be a relevant statistic, especially if the institution chooses to "leg into" a 100,000 share position by executing several trades (see, for example, Keim and Madhavan, 1995). Thus, if the goal is to measure the effect of sixteenths on trading costs, there is no substitute for direct evidence on trading costs. In this paper, we use a large, proprietary sample of institutional trades to provide such a direct measure.

The evidence from these institutional trades paints a much different picture of the change to sixteenths. For these market participants, the cost of small NYSE trades (less than 10,000 shares) is little changed by the advent of sixteenths. However, NYSE trades of at least 10,000 shares are more expensive to execute when prices are quoted in sixteenths, and the cost differential increases with order size. Overall, for the institutions studied here, the move to sixteenths has resulted in substantially *increased* trading costs for stocks listed on the NYSE.[1]

Our results suggest that small traders may benefit from tighter quoted spreads while institutions pay more to execute larger trades. Thus, the change to sixteenths does not appear to be pareto-improving. Our results are also consistent with a study by Goldstein and Kavajecz (1998) which shows that when sixteenths were adopted by the NYSE, not only did depth decline at the quoted spread, but the entire limit order book was reduced on either side of the inside quotes. In fact, Goldstein and Kavajecz (1998) show that execution costs increase for hypothetical large orders executed entirely against the limit order book after the change to sixteenths.

---

[1] The point estimates of the cost differences for Nasdaq stocks are similar. However, the institutions in this sample execute relatively few trades in Nasdaq stocks, reducing the power of the statistical tests.

The rest of this paper is organized as follows. Section 2 uses the Trades and Quotes (TAQ) data to calculate standard market liquidity measures, including quoted and effective spreads and quoted depths, before and after the NYSE and Nasdaq events. In section 3, we directly measure institutional trading costs around the adoption of sixteenths. Section 4 draws some conclusions.

2. Spreads and depths (TAQ data)

Prior to June 24, 1997, NYSE Rule 62 specified that NYSE stocks with a share price of at least $1 were quoted and traded using a minimum tick size of 1/8, so nearly all NYSE stocks were affected by the change to sixteenths. On Nasdaq, the June 1997 change was not as far-reaching, simply because Nasdaq had already adopted a finer price increment in many areas. For example, the tick size was already $1/16^{th}$ for quoted share prices under $10.[2] Furthermore, while higher priced stocks could only be quoted in eighths before June 1997, the minimum price increment for transactions was (and is) constrained only by the requirement that the denominator be an integer power of 2. While most retail trades took place on eighths during this time period, it was not uncommon to see institutional trades recorded in 32^{nd}'s and 64^{th}'s. Thus, it would not be surprising to find that the adoption of sixteenths has smaller effects on Nasdaq, even for stocks trading above $10.

To evaluate these tick size reductions, we begin by calculating standard measures of market quality and liquidity before and after the NYSE and Nasdaq sixteenths events (see Huang and Stoll (1996) for a useful summary of these measures). To be included in the full sample of firms, common stocks must have at least one trade and one valid quote on at least 20 of the 40

[2] In fact, Bessembinder (1990) uses this institutional feature to examine the effects of the change in tick size as Nasdaq stocks rise above, or fall below, $10 per share.

trading days before the relevant market (NYSE or Nasdaq) changes to sixteenths. Stocks must also meet the same data requirement for the 40-day period after the tick size change, and their 1996 year-end share price must exceed $10.[3] This results in 1,608 NYSE firms and 1,518 Nasdaq firms.

For each exchange, we form quartiles based on the market value of equity using year-end 1996 data from CRSP. Summary statistics for this sample are shown in the first part of the two panels in Table 1. Statistics for NYSE firms are reported in Panel A, while statistics for Nasdaq firms are reported in Panel B. NYSE average market capitalization ranges from $234 million for the smallest quartile to $13.3 billion for the largest quartile. Note that the size quartiles differ across exchanges, reflecting the fact that Nasdaq firms are generally smaller. For example, the top quartile of Nasdaq firms (with an average market cap of $2.2 billion) is quite similar to the third quartile of NYSE firms (with an average market cap of $1.9 billion).

Table 2 reports average time-weighted quoted spreads and depths before and after the adoption of sixteenths. Consistent with the experience of other exchanges which have reduced tick size, there is a substantial decline in NYSE quoted spreads (displayed in Panel A) beginning June 24, 1997. Across all firms in the sample, quoted spreads average $0.184 during the 40 trading days before the change; they average $0.155 in the 40 trading days after sixteenths are introduced. Expressed as a proportion of the midpoint of the quote, quoted spreads fall from 0.68% to 0.53%, a decline of over 20 percent. This relative decline in quoted spreads is fairly uniform across different firm sizes. For example, spreads on the smallest NYSE stocks fall from 1.08% to 0.91%, while spreads on stocks in the largest quartile fall from 0.35% to 0.25%.

[3] As noted above, stocks with share prices below $10 are unaffected by the June 1997 change to sixteenths.

Nasdaq spreads are summarized in Table 2 Panel B. Nasdaq quoted spreads are higher than NYSE quoted spreads, which is due in part to the fact that Nasdaq firms are smaller and less liquid. The relative decline in spreads at the introduction of sixteenths is quite similar, however. Across all Nasdaq firms, quoted proportional spreads decline from 2.26% before the June 2, 1997 tick size reduction to 1.88% afterward. For the largest quartile of Nasdaq stocks, quoted proportional spreads fall from 1.17% to 0.88%.

Statistical tests for a structural break at the sixteenths event are performed using the time series of daily mean spreads, which are assumed to be independent over time. In addition to being economically important changes, all the spread declines are highly statistically significant.

While sixteenths bring smaller quoted spreads, they also are associated with changes in quoted depth, also reported in Table 2. For example, across all the NYSE firms in our sample, depth at the bid declines from an average of 5,699 shares in the last two months of eighths to an average of 3,707 shares in the first two months of sixteenths, a substantial decline. Similar changes are observed for quoted ask depths. Most of the decline in quoted depth is concentrated in the larger NYSE firms. For example, average quoted bid depth for the smallest NYSE quartile is not significantly different pre- and post-sixteenths, while average quoted ask depth for the largest NYSE quartile falls by about 4,000 shares, from about 9,000 shares to about 5,000 shares.[4]

Nasdaq quoted depth generally increases, but the change is not substantial. The lack of significant change in Nasdaq quoted depth may be due to a reporting feature of that exchange. When multiple market makers quote identical depths at the best quote, the depth of only one market maker is reported. Thus, whether two market makers or five market makers are quoting

1,000 share depth at the best quote, only 1,000 shares is reported. In addition, the vast majority of Nasdaq dealer quotes are for 1,000 shares, since there are few incentives for a market maker to quote additional depth beyond 1,000 shares. For this reason, it is difficult to draw conclusions about changes in Nasdaq quoted depth from our analysis.

In any case, one ought not assign too much importance to quoted depth as a measure of liquidity. While liquidity providers are obligated to honor their posted quotes (up to their posted depths), traders can often obtain better prices or trade amounts larger than the quoted depth at the quoted price. For this reason, a better measure of trading costs relative to quoted prices is the effective spread, which is defined as twice the difference between the execution price and the midpoint of the prevailing quote. Table 3 reports dollar-volume weighted effective spreads before and after the introduction of sixteenths on the Nasdaq and NYSE. Across all the NYSE firms in the sample (Panel A), effective spreads average $0.154 in the forty trading days before the switch and $0.138 in the forty trading days following the switch. On a proportional basis, effective NYSE spreads average 0.569% before the change in the minimum price increment and 0.465% afterward. All these declines are highly significant and economically substantial, since they indicate a reduction in spread-related trading costs on the order of twenty percent.

Nasdaq effective spreads are reported in Panel B of Table 3. Sixteenths also lead to declines in this market, though of somewhat smaller magnitude. Average dollar effective spreads go from $0.329 to $0.315. On a proportional basis, average effective spreads go from 1.63% to 1.40%. These represent declines in spread-related trading costs on the order of 14%.

Table 3 also shows that sixteenths are associated with declines in effective spreads across firms of all sizes. The relative decline is somewhat more pronounced for large firms. For

---

[4] Using limit-order book data from the NYSE, Goldstein and Kavajecz (1998) show that depth away from the best

example, effective spreads for the largest NYSE quartile decline from 0.32% to 0.24%, a 23% decline, while effective spreads for the smallest NYSE quartile decline from 0.86% to 0.75%, a 13% decline. On the Nasdaq, the largest quartile on average sees a 20% decline in proportional effective spreads, while the smallest quartile experiences a 12% decline.

However, Table 3 provides the first hint that the reduction in effective spreads is not uniform across *trades* of all sizes. When transactions are partitioned based on the number of shares traded, sixteenths are associated with smaller dollar effective spreads as long as the trade size is less than 100,000 shares. For the very largest trades of at least 100,000 shares, effective spreads are indistinguishable before and after the adoption of sixteenths. This is true for both the NYSE and Nasdaq; NYSE dollar effective spreads go from 22.4 cents to 21.7 cents, while Nasdaq effective spreads for these large trades are 23.7 cents pre-sixteenths and 23.1 cents afterward.

Overall, the TAQ evidence on spreads would seem to indicate that sixteenths are associated with an overall decline in trading costs. However, spreads are not necessarily an accurate measure of the cost of trading, and we turn next to a direct measure of trading costs.

3. Institutional trading costs (Plexus data)

In contrast to small volume traders, institutions tend to trade larger quantities. They also tend to establish or liquidate a position slowly over time. These portfolio changes may take several days and many transactions to complete. Unfortunately, traditional spread measures do not take into account all of the costs associated with these trading strategies. In particular, establishing a position using multiple transactions is likely to move prices adversely, increasing the total cost of establishing the position (see, for example, Jones and Lipson, 1997). In addition,

---

bid and offer also declines after the adoption of sixteenths.

large orders may trade through a portion of the limit order book and, therefore, access liquidity beyond what is available at the quote.

In such cases, information on trades and quotes is inadequate for measuring trading costs. However, we are able to directly measure realized trading costs for a sample of institutional equity orders provided to us by the Plexus Group.[5] Specifically, this sample contains Plexus client equity trades within 40 trading days of the NYSE and Nasdaq changes to sixteenths.

The data include:

(a) the date and time at which an order is released to a firm's trading desk,

(b) the weighted average transaction price during the ten minute period that the order is released to the trading desk,

(c) the execution price reported by each broker executing the order, and

(d) any commissions paid to brokers.

We examine both implementation costs and the sum of implementation costs and commissions (total costs). We define implementation cost as the proportional difference between the volume-weighted average execution price of trades executed as part of the order, and the price prevailing at the time the institution released the order to its trading desk. The prevailing price is the average transaction price over the 10-minute interval during which the order was released.

Our definition of implementation costs captures as closely as possible the execution costs incurred by traders wishing to establish a position in a given stock. Most important, when more

[5] The Plexus Group is a widely recognized consulting firm that monitors the costs of institutional trading. Their clients manage over $750 billion in equity assets and the firm has access to trading records covering approximately 20% of marketplace volume. Plexus clients include Scudder, State Street Global and Alliance. In addition to Plexus Group (1996) and other similar reports, Plexus data have also been examined by Keim and Madhavan (1995, 1997), Jones and Lipson (1997), and Conrad, Johnson, and Wahal (1997).

than one trade is executed to complete an order, this measure includes any additional costs incurred as prices move in response to a trader's earlier activities. For example, as a trader makes multiple purchases of a security, the price would be expected to rise making later purchases more expensive than earlier ones.

There are other avenues through which information on an institution's order can affect market prices. For example, the trading desk may contact market makers off the exchange floor to obtain price indications. Alternatively, the desk may instruct a broker to work the order at the trading post. Such actions may provide important information to other market participants. These "information leakages" may precede order execution and may significantly impact trading costs even when orders are executed in a single trade. The prevailing price at the time an order is released to the trading desk, therefore, captures the price before any information on the order is likely to have reached the market.

Table 1 presents summary statistics on the trades of Plexus clients. Filters exclude all firms with year-end 1996 share prices below $10 per share (in order to match the TAQ sample analyzed in Section 2), all orders that require more than one week to execute, and all orders with implementation costs exceeding 20%. Plexus clients execute trades in a wide cross-section of listed stocks, with 259,947 orders in 1,436 NYSE stocks (Panel A) and 97,536 orders in 1,272 Nasdaq stocks.[6] Naturally, these large institutional traders are much more likely to trade in larger stocks. For example, Plexus client volume in the largest NYSE stocks (quartile 4) averages $7 million (about 140,000 shares) per stock per day; corresponding figures for Nasdaq

---

[6] We refer to a record in the Plexus dataset as a trade. However, a Plexus record may represent either a single trade, or multiple trades in one stock on one day aggregated together by a broker. This does not impact our measures of trading costs, since the dataset records the desired weighted-average execution price. However, the number of Plexus trades reported in Table 1 may understate the actual number of Plexus client transactions.

are $2 million and 50,000 shares. In fact, stocks in the largest quartiles account for about 80% of Plexus dollar volume. However, Plexus clients represent a similar fraction of total trading volume across all size categories. For example, Plexus clients account for about $102,000 (or 14%) of the $745,000 average daily volume in NYSE quartile 1 stocks (the smallest quartile). For NYSE quartile 4 stocks, Plexus clients account for 16% of total trading volume.

Table 4 presents an initial look at the Plexus trading cost data before and after the NYSE and Nasdaq change to sixteenths. Since implementation costs and total costs yield essentially identical conclusions, we focus on total costs including commissions. The sample is also partitioned based on the number of shares traded.

There are two striking features of the NYSE data: (a) sixteenths are associated overall with a marked increase in trading costs for these institutions, and (b) the increases are most pronounced for large trades.

For the institutions in this sample, trading costs for NYSE trades of less than 10,000 shares are about the same whether the minimum tick is eighths or sixteenths. Specifically, total costs for orders of less than 1,000 shares go from 24 basis points in the 40 trading days before June 24, 1997 to 23 basis points afterward.[7] Orders between 1,000 shares and 9,999 shares average a total cost of 33 basis points pre-sixteenths vs. 35 afterward. Neither change is statistically distinguishable from zero.[8]

For large trades, however, sixteenths result in an *increase* in trading costs. For trade sizes between 10,000 and 99,999 shares, total costs for NYSE stocks are 42.4 basis points when securities trade on eighths and 49.3 basis points when securities trade on sixteenths. This

[7] All reported average costs are weighted by dollar volume to reflect the proportional costs of trading a representative Plexus client portfolio.
[8] Standard errors are calculated using the daily time series of trading costs, assuming independence over time.

represents over a 16% increase in execution costs. The situation is even more dramatic for the very largest trades of at least 100,000 shares. The imposition of sixteenths is associated with a dramatic rise in execution costs, from 61.1 basis points before to 100.1 basis points after. Overall, the dollar-volume-weighted average trading cost for these Plexus clients goes from 49.9 basis points prior to June 24 to 72.8 basis points afterward, an increase of over 40%. The overall figure is clearly driven by the larger trades. This makes sense; while smaller trades are cheaper under sixteenths, they represent a relatively small fraction of the total amount traded. Thus, for the institutions in this sample, the move to sixteenths has resulted in *increased* trading costs.

Table 4 Panel B reports the institutional trading costs for Nasdaq stocks before and after June 2, 1997. Sixteenths are associated with an increase in trading costs of about 18 basis points overall. There is at most a seven basis point increase for trades of less than 100,000 shares. Again, the largest trades (at least 100,000 shares) exhibit the largest increases in costs, with point estimates of the cost increase equal to about 39 basis points. None of these cost increases are statistically reliable, however. For small trade sizes, the estimated cost differences are small, and so these test results are not surprising. The hypothesis test results for the largest trade-size category may be a result of low power due to the relative paucity of large Nasdaq trades by Plexus clients (only 3,546 trades of at least 100,000 shares). Alternatively, it could be the case that a change in the minimum tick size has minimal effects on institutional trading costs in a dealer-driven market.

One possible confounding explanation for the above results is that the trade size partitions do not control adequately for differences in trade size pre- and post-event. For example, the increase in costs for the very largest NYSE trades could be due to a shift to larger trades after sixteenths are introduced. To investigate this possibility, we estimate the following

regression for each NYSE and Nasdaq stock traded by Plexus clients at least 100 times in the 40 trading days before and after the introduction of sixteenths:

$$C_i = \alpha_0 + \alpha_1 POST_i + \alpha_2 VOLUME_i + \varepsilon_i$$

where the dependent variable is either implementation cost or total cost, $POST_I$ is a dummy variable equal to one if the order was completed after the change to sixteenths, and $VOLUME_I$ is the size of the order in millions of dollars. This provides a linear control for the size of the executed order.

Cross-sectional averages of the estimated coefficients are reported in Table 5. The increase in total costs following the adoption of sixteenths is estimated at 3.0 basis points for NYSE stocks and 7.0 basis points for Nasdaq stocks. Neither of these increases is stistically reliable. These numbers are much smaller than the overall increases of 23 and 18 basis points for NYSE and Nasdaq stocks that are reported in Table 4. The explanation is that the Table 5 regression provides equal weight to each trade, regardless of its size. Under these weighting assumptions, the regression is dominated by small trades which are relatively unaffected by the tick change. Of course, for an institution managing its trading costs, these weighting assumptions are inappropriate. Unfortunately, this regression framework is poorly suited to an analysis of an institution's total trading costs, since volume-weighting does not make any sense in a regression context where volume is a right-hand-side control variable.

A better approach is to create a matched sample of trades before and after the imposition of sixteenths. To ensure that trade pairs are identical except for the underlying tick size, trade pairs must be in the same stock and for the same number of shares (with a tolerance of 1%). Fortunately, the sample is sufficiently large, and institutional trading behavior sufficiently stationary, that over 70,000 pairs result.

The results of the matched pair analysis are reported in Table 6. The results strongly confirm the findings of Table 4. Small NYSE trades of less than 1,000 shares become marginally cheaper following the introduction of sixteenths, with a decline in total trading costs of about 3 basis points. Total trading costs rise by about 3 basis points for NYSE trades between 1,000 and 9,999 shares. Large trades of at least 10,000 shares become significantly more expensive under sixteenths, with a cost increase of over 25 basis points for the very largest NYSE trades.

The results for Nasdaq are in line with the earlier estimates from Table 4. Costs under sixteenths are within five basis points of total costs under the eighths regime for all trade-size categories of less than 100,000 shares. There are only 484 matched trade pairs of at least 100,000 shares, and so the point estimate of a 21 basis point increase in total costs for these trades is not reliably different from zero.

Finally, we sort the Plexus sample based on the market capitalization of the traded stocks. The vast majority of Plexus client trades turn out to be in the largest stocks, which makes it very difficult to conduct inference with appreciable power concerning the costs of trading smaller stocks. For example, 44,000 of the 55,000 NYSE orders are in the largest quartile stocks. For Nasdaq, 12,500 of the 15,000 orders are for stocks in the largest quartile. Of course, most trading activity is clustered in the largest stocks, so any study of the aggregate trading costs faced by a particular investing group is essentially a study of trades in the largest stocks.

4. Discussion and conclusions

The evidence presented here suggests that the institutions in the Plexus dataset bear increased trading costs under sixteenths for otherwise identical trades. These institutions also

bear increased trading costs overall under sixteenths, after adjusting for changes in trading behavior induced by the tick size reduction. It is possible that the adoption of sixteenths has provided some benefits to these institutions that we have been unable to measure here. However, it seems hard to believe that such benefits would outweigh the substantial increase in observed trading costs, and it seems reasonable to conclude that the institutions in the Plexus dataset are worse off under sixteenths.

The immediate lesson of this exercise is that measures such as spreads are not a sufficient statistic for market quality. In particular, our results imply that effective spreads are not a sufficient statistic for institutional trading costs. However, we are not sure why spread measures are such a misleading indicator of institutional trading costs. We have proposed an explanation based on accumulating or liquidating a position over the course of several trades, but we do not know of any empirical work that directly supports or refutes this explanation. In addition, changes in the depth available from limit orders or changes in trading strategies as a result of new institutional features may explain the differences.

Our results may also explain some earlier tick size findings. For example, when the Toronto Stock Exchange (TSE) moved to sixteenths in April 1996, the share of TSE order flow in NYSE listed stocks did not increase (see Ahn, Cao and Choe (1998)). At first glance, this result is surprising, since the lower TSE spreads would presumably attract additional order flow in dual-listed stocks. Our findings suggest that lower TSE spreads might not be accompanied by lower trading costs for institutional traders; this could explain the lack of change in TSE market share for cross-listed stocks.

Our results can also be viewed in light of Glosten (1995), who models the effect of price discreteness on market-makers, small traders, and large traders. That model predicts that a

reduction in tick size benefits those who trade small quantities and has essentially no effect on those who trade large quantities. Our evidence is not consistent with the model's predictions concerning large traders.

Finally, this analysis has potentially important policy implications. It appears that a smaller tick size is associated, among other things, with a transfer from institutions to smaller traders who benefit directly from narrower spreads. Since institutions appear to be losers, a smaller tick size does not appear to be pareto-improving per se. However, it remains an open question as to whether the benefits to smaller traders and others might outweigh the costs that we have identified here. In any case, the results suggest that institutional traders should, as a group, regard skeptically any proposal for a further reduction in minimum price increments.

REFERENCES

Ahn, Hee-Joon, Charles Q. Cao, and Hyuk Choe (1998), "Decimalization and competition among exchanges: evidence from the Toronto Stock Exchange cross-listed securities,"Journal of Financial Markets 1:51-87.

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

Conrad, Jennifer, Kevin Johnson, and Sunil Wahal (1997), "Institutional trading and soft dollars," working paper, University of North Carolina.

Glosten, Lawrence (1995), "Competition and the set of allowable prices," working paper, Columbia University.

Goldstein, Michael A. and Kenneth A. Kavajecz (1998), "Eighths, sixteenths, and market depth: changes in tick size and liquidity provision on the NYSE," working paper, University of Pennsylvania.

Harris, L. (1997), "Decimalization: a review of the arguments and evidence," working paper, University of Southern California.

Huang, Roger D. and Hans R. Stoll (1996), "Dealer versus auction markets: A paired comparison of execution costs on NASDAQ and the NYSE", Journal of Financial Economics 41:343-357.

Jones, Charles M. and Marc L. Lipson (1997), "Execution costs of institutional equity orders," working paper, Columbia University.

Keim, Donald B. and Ananth Madhavan, (1995), "Anatomy of the trading process: empirical evidence on the behavior of institutional traders," Journal of Financial Economics 37:371-398.

Keim, Donald B. and Ananth Madhavan (1997), "Transactions costs and investment style: an inter-exchange analysis of institutional equity trades," Journal of Financial Economics 46:265-292.

Plexus Group (1996), "Quality of trade execution in comparative spreads: AMEX vs. NASDAQ vs. NYSE", Plexus Group, Santa Monica CA.

Ricker, Jeffrey P. (1998), "Breaking the eighth: sixteenths on the New York Stock Exchange," working paper.

Ronen, Tavy and Daniel G. Weaver (1998), "'Teenies anyone? The case of the American Stock Exchange," working paper, Baruch College.

Porter, D. and D. Weaver (1997), "Decimalization and market quality," Financial Management 26:5-26.