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Sixteenths: direct evidence on institutional execution costs☆

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Abstract

In June 1997, the New York Stock Exchange lowered its minimum price increment on most stocks from eighths to sixteenths. We use a sample of institutional trades to directly measure the effect of this tick size reduction on execution costs. Though quoted and effective spreads decline, realized execution costs for these institutions increase after the change to sixteenths. Costs increase most for orders that aggressively demand liquidity, including large orders, orders placed by momentum traders, and orders not worked by the trading desk. These findings emphasize that spreads are not a sufficient statistic for market quality. Smaller tick sizes may actually reduce market liquidity. © 2001 Elsevier Science S.A. All rights reserved.

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1. Introduction

On June 24, 1997, the New York Stock Exchange (NYSE) lowered its minimum price increment on most stocks from eighths of a dollar to sixteenths of a dollar. According to the NYSE, this change is an interim step in a move toward the decimalization of prices and price increments. However, there is considerable debate among regulators, practitioners, and academics about the optimal minimum price increment or tick size. In this paper, we add new empirical evidence to the debate. Specifically, we use a proprietary data set of institutional orders to gauge the effect of this tick size reduction on realized execution costs.

Many stock exchanges have recently reduced their minimum ticks, and these changes have been carefully studied. For example, Bacidore (1997), Porter and Weaver (1997), and Ahn et al. (1998), among others, examine the effects of the April 1996 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), and Bollen and Whaley (1998) examine the NYSE change to sixteenths. Bessembinder (1997) examines Nasdaq stocks that change on an individual basis to or from sixteenths. Most of these studies examine trades, inside quotes, and effective spreads, calculated as the difference between execution prices and the prevailing mid-quote. In every case, quoted bid–ask spreads and effective spreads decline when tick size is reduced. These findings are commonly interpreted as evidence of a decline in execution costs, and thus as an improvement in market quality (see Ricker, 1998, for example).

The articles cited above often note that depth at the inside quote declines when the minimum tick is reduced. By itself, this is not surprising. Decreased quote sizes would be expected even with a fixed upward sloping liquidity supply curve. For example, suppose that market-makers are willing to supply 10,000 shares at a 1/8 spread pre-sixteenths. Post-sixteenths, they might be willing to supply 4,000 shares at a 1/16 spread and the balance of 6,000 shares at a 1/8 spread. In this example, depth at the inside quote is lower, but cumulative depth at a fixed spread is unchanged. Thus, studies of quoted depth alone cannot address the key question of whether the liquidity supply curve shifts following the adoption of smaller price increments.

Goldstein and Kavajecz (2000) examine the NYSE change to sixteenths using proprietary NYSE system data and provide important additional evidence on depth and trading costs. They reconstruct the entire limit order book around the change in tick size. For the 100 stocks they examine, depth decreases throughout the limit order book under sixteenths. This finding suggests there is a reduction in the overall willingness of traders to submit limit orders and, therefore, a potential reduction in depth. However, when they proceed to measure effective spreads in their sample, their findings are similar to those in other studies.

Specifically, they find that effective spreads generally decline, though there appears to be some increase for the largest trades in low-volume stocks.

How can effective spreads and limit order book depth both decline with the change to sixteenths? One explanation is that the electronic limit order book does not measure total depth. The floor, including specialists and floor traders, provides considerable liquidity that is often undisplayed (see Sofianos and Werner, 1997). Thus, the reduction in limit order book depth may reflect a simple substitution. After the tick reduction, more orders may be sent to the floor rather than to the book. If so, total liquidity available in the market may be unchanged or even improved.[1]

However, effective spreads are also an imperfect measure of trading costs, especially for larger orders. There are two main reasons. First, institutions are affected by price moves over time, because they often "leg into" large positions by executing multiple trades (see Keim and Madhavan, 1995; Economides and Schwartz, 1995). Second, there may be information leakage prior to execution (see Plexus Group, 1996). If quotes move up in anticipation of a buy order or down in anticipation of a sell order, an effective spread measure will understate the actual cost of execution. In fact, information leakage may be most severe when traders are the least willing to display depth in the limit order book.

In this paper, we avoid the limitations inherent in effective spread measures by examining a large proprietary sample of institutional orders for which total execution costs can be measured directly. Our results paint a different picture of the change to sixteenths. The cost of small institutional orders of less than 1,000 shares does indeed decline, and medium orders of 1,000 to 9,999 shares are essentially unaffected by the tick size reduction. However, the similarities to earlier findings end at this point. In all of our partitions of the data, we find that liquidity demanders pay more under sixteenths. For example, orders of at least 10,000 shares cost more with a smaller tick. Institutional orders that are at least 100,000 shares cost one-third more to execute after the change to sixteenths. Momentum traders as a group pay one-third more to execute post-sixteenths. And execution costs are over 50% higher under sixteenths for orders executed in a single day by a single broker. Such orders typically demand more liquidity, since the institution in this case is not willing to execute the order over multiple days or engage multiple brokers. Overall, for the institutions studied here, the move to sixteenths has resulted in increased execution costs for NYSE stocks.

The changes we document are most pronounced for the NYSE stocks with the lowest quoted spreads before the change. This finding makes sense, since spreads are more likely to be constrained by the minimum tick for these stocks. In the smallest spread quartile, sixteenths are associated with large cost savings for

[1] This interpretation is consistent with Goldstein and Kavajecz (1999), who find that on the day following the large market drop in October 1998, there was a dramatic decline in limit order book depth, but quoted depths, which reflect specialist and trading floor interests, declined only slightly.

small trades.[2] However, this grouping is also where we find the largest increase in execution costs for larger orders.

While our results differ from studies of trades and quotes, they are consistent with some of the theoretical work on minimum tick size. For example, Harris (1990, 1996), Anshuman and Kalay (1998), and Seppi (1997) provide theoretical frameworks in which smaller tick sizes imply less liquidity.[3] In all of these models, smaller price increments allow market participants to step ahead of existing limit orders at less cost, which increases the cost of limit orders relative to market orders.

In general, our results, taken together with the evidence in Goldstein and Kavajecz (2000), suggest that traders are in fact less willing to commit to providing liquidity after a tick size reduction. This response leads to increased trading costs for orders that demand liquidity. Of course, traders who execute small trades at quoted spreads are better off after the change to sixteenths. But the change to sixteenths does not appear to be pareto-improving.

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 tick size reduction. In Section 3, we directly measure institutional execution costs around the adoption of sixteenths. Section 4 presents a regression analysis of execution costs that controls for firm, market, and order characteristics. Section 5 draws some conclusions.

2. Spreads and depths

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. When the minimum tick size was reduced to sixteenths of a dollar, nearly all NYSE stocks were affected.

To evaluate the tick size reduction, we begin by calculating standard measures of execution costs and liquidity before and after the sixteenths event.[4] To be included in this analysis, a stock must have at least one trade and one valid quote on at least one of the 100 trading days before the change to sixteenths. Stocks must also meet the same data requirement for the 100-day period after

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[2] These findings are related to those of Bollen and Whaley (1998), who show that the effect of sixteenths on NYSE spreads is most pronounced for low-priced stocks.

[3] See Harris (1997) for a comprehensive summary of theoretical, practical, and empirical issues associated with decimalization and tick size.

[4] Bessembinder and Kaufman (1997), Huang and Stoll (1996), and Christie and Huang (1994) are examples of studies that apply similar trading cost and liquidity measures in other contexts.

the tick size change, and their 1996 year-end share price must exceed \$1. We restrict our analysis to common stocks and eliminate those stocks with stock splits and those stocks that switched exchanges during the 200-day study period. The net result of these filters is a sample of 1,690 firms traded on the NYSE.

Summary statistics for our samples are shown in Panel A of Table 1. Average market capitalization and closing share price, based on year-end 1996 data from the Center for Research on Security Prices, are \$4.6 billion and \$35, respectively. Panel B of Table 1 describes the trading activity of our sample firms using Trades and Quotes (TAQ) data provided by the NYSE as well as our data on institutional trades. Table 1 presents some evidence that the average trade size is smaller after the change to sixteenths. The average trade size falls from 1,855 shares to 1,613 shares, a drop of over 240 shares. Since total volume rises, there are at least two possible explanations. First, sixteenths may induce more small trades, perhaps because spreads are smaller. Another possibility is that large traders respond to sixteenths by breaking up their orders into smaller constituent pieces.

Next, the 1,690 NYSE common stocks are assigned to quartiles based on their average dollar quoted spread during the last 10 trading days of 1996. Panel A of Table 2 reports additional summary statistics for each of the subsamples. Naturally, the firms with the smallest spreads are those with the largest market capitalization and largest trading volume. For example, daily dollar volume across the four quartiles averages \$22 million, \$17 million, \$7 million, and \$3 million.

Panel B of Table 2 reports the effect of sixteenths on quoted spreads and depths (see Bollen and Whaley, 1998, for a more extensive analysis of NYSE trade and quote data around the tick size reduction). Across all firms in the sample, volume-weighted quoted spreads average \$0.180 during the 100 trading days before the change, and \$0.155 in the 100 trading days afterwards. Expressed as a proportion of the midpoint of the quote, quoted spreads fall from 0.93% to 0.69%, a decline of over 25%. 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. We strongly reject the null hypothesis of no change. A similar reduction is also observed for dollar-weighted effective spreads, defined as twice the difference between the transaction price and the prevailing mid-quote. As expected, the effect of the change to sixteenths is more pronounced for the firms with the smallest spreads prior to the change. For example, effective spreads for these firms fall by about one-third, going from 1.20% pre-sixteenths to 0.77% post-sixteenths. Firms with the largest spreads experience only modest reductions. For instance, quoted spreads in the largest spread quartile are 23.8 cents under eighths and 22.6 cents under sixteenths, while effective spreads go from 0.70% under eighths to 0.60% under sixteenths.

Table 1
Summary statistics

Summary statistics for a comprehensive sample of NYSE common stocks, and a sample of institutional orders provided by the Plexus Group, before and after the adoption of sixteenths on June 24, 1997. All averages are equally weighted means across firms. Stock price and market capitalization are calculated as of year-end 1996 using the Center for Research in Securities Prices (CRSP) database. Trading activity measures for the comprehensive sample are obtained from the TAQ (Trades and Quotes) database. Tests of significance are calculated using the standard error of the time series of daily mean values. An asterisk signifies that the change from pre-sixteenths is significant at the 5% level.

Panel A: Firm characteristics		
All firms		
Stock price	$35.39	
Market capitalization (millions)	$4,639	
Number of firms	1,690	
Firms with plexus orders		
Stock price	$28.29	
Market capitalization (millions)	$3,106	
Number of firms	1,271	
	Pre-change	Post-change
Panel B: Trading activity		
Daily share volume		
All trades	257,205	287,714
Plexus orders	36,630	38,148
Daily dollar volume ($ thousands)		
All trades	11,263	13,208*
Plexus orders	1,456	1,741*
Daily number of trades/orders		
All trades	130.16	163.01*
Plexus orders	1.47	1.56*
Average trade/order size (shares)		
All trades	1,855	1,613*
Plexus orders	25,129	24,368
Average trade/order size ($ thousands)		
All trades	55	53*
Plexus orders	997	1,112*

Consistent with other research, we find that the quoted depth declines significantly. For example, across all the firms in our sample, the average of bid and offered depth declines by about one-third, from 5,995 shares to 3,808 shares after the move to sixteenths. The biggest changes in quoted depth occur in firms with small spreads, and the effect declines monotonically across spread

Table 2
The NYSE move to sixteenths: spreads and depths by spread categories

Spread quartiles are assigned using the average quoted spread over the last 10 trading days of 1996, which is prior to the study period. Each spread quartile contains approximately 422 of the 1,690 firms in the sample. Panel A contains summary statistics. Average share price and market capitalization are year-end 1996 figures. Other statistics are averages per stock over the 200-day sample period. Panel B contains mean quoted spreads, both in dollars and as a percent of the quote midpoint, and quoted depths from the TAQ database. Effective spreads are twice the difference between the transaction price and the prevailing mid-quote. Data include all quotes within 100 trading days before and after the June 1997 change in tick size. Presented figures are averages over time of daily volume-weighted averages across firms. Tests of significance are calculated using the standard error of the time series of daily mean values. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively.

		Spread quartiles			
	All firms	1 (Smallest)	2	3	4 (Largest)
Panel A: Quartile characteristics					
Average share price	35.39	25.99	34.73	36.16	44.67
Market cap ($ millions)	4,639	8,835	6,023	2,289	1,409
Average trade size (shares)	1,734	2,093	1,847	1,590	1,394
Average trade size ($)	53,863	48,621	61,454	55,077	50,166
Daily volume (shares)	272,459	588,520	313,180	130,147	58,230
Daily volume ($ thousands)	12,237	22,053	17,085	6,663	3,147
Daily number of trades	147	295	175	78	38
Panel B: Spreads and depths					
Quoted dollar spread ($)					
Before	0.180	0.140	0.161	0.185	0.238
After	0.155	0.103	0.132	0.161	0.226
Net change	− 0.025***	− 0.037***	− 0.029***	− 0.024***	− 0.012***
Quoted proportional spread (%)					
Before	0.934	1.271	0.796	0.824	0.839
After	0.686	0.809	0.597	0.650	0.685
Net change	− 0.248***	− 0.462***	− 0.199***	− 0.174***	− 0.154***
Effective spread (%)					
Before	0.822	1.198	0.699	0.690	0.696
After	0.623	0.771	0.545	0.577	0.597
Net change	− 0.199***	− 0.427***	− 0.154***	− 0.113***	− 0.099***
Average of bid and ask depth (shares)					
Before	5,995	12,540	5,563	3,517	2,203
After	3,808	6,851	3,775	2,624	1,934
Net change	−2,187**	−5,689***	−1,788***	− 893***	− 269***

Table 3
The NYSE move to sixteenths: effective spreads across trade size categories

Mean effective spreads, both in dollars and as a percent of the quote midpoint. Data include all trades within 100 trading days of the June 1997 change in tick size. Presented figures are averages over time of dollar volume-weighted daily averages across firms within each specified grouping of firms or trades. Tests of significance are calculated using the standard error of the time series of daily mean values. Significance at the 1% level is denoted by ***.

	Dollar effective spread ($)			Proportional effective spread (%)		
	Before	After	Net change	Before	After	Net change
All trades	0.157	0.141	− 0.016***	0.822	0.623	− 0.199***
Trade size categories (shares)						
Less than 1,000	0.134	0.114	− 0.020***	0.712	0.507	− 0.205***
1,000 to 9,999	0.153	0.136	− 0.017***	0.802	0.606	− 0.196***
10,000 to 99,999	0.155	0.141	− 0.014***	0.697	0.537	− 0.160***
More than 99,999	0.227	0.216	− 0.011***	0.890	0.706	− 0.184***

categories. Quoted depth for the smallest spread firms falls from 12,540 shares pre-event to 6,851 shares post-event, a 45% reduction. Quoted depth for the large-spread quartile falls from 2,203 shares to 1,934, a 12% decline.

As noted above, neither depth nor quoted spread is an adequate measure of trading costs. Effective spreads, defined as twice the difference between the transaction price and the prevailing quote midpoint prior to the transaction, are a more accurate measure since trades do not always execute at the posted quotes. Some orders may be executed inside the posted quote. Large orders that exceed the posted depth may be transacted at less favorable prices. To investigate differences between small and large trades, Table 3 presents dollar and proportional effective spreads for four trade-size categories. Across all trade sizes, sixteenths are associated with reduced effective spreads. For example, the effective dollar spread for trades of at most 1,000 shares declines from 13.4 cents to 11.4 cents. The effective proportional spread for these small trades goes from 0.712% pre-event to 0.507% afterwards, a 27% reduction. The effective proportional spread for the largest trades of at least 100,000 shares declines from 0.890% to 0.706%, a 21% reduction. There are similar declines across other trade sizes.

Thus, even though Goldstein and Kavajecz (2000) find that the limit order book is emptier after the change to sixteenths, the effective spread evidence here and in other papers points to uniformly lower execution costs under sixteenths. This finding suggests that either total depth, including undisplayed interests, has not changed, or that the effect of reduced depth is outweighed by the effect of smaller spreads for the inframarginal part of the trade. However, we will argue in the next section that even effective spreads are not necessarily an accurate measure of the cost of trading. Instead, researchers need to measure execution costs directly.

3. Institutional execution costs

Institutions tend to trade relatively large quantities of stock. They also tend to establish or liquidate positions 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, 1999). In addition, there may be information leakage when a large order is brought to the floor or shopped around in the upstairs market. Prices may move adversely even before any part of the order is filled.

In such cases, information on trades and quotes is inadequate for measuring execution costs. Fortunately, we are able to directly measure realized execution costs for a sample of institutional equity orders provided by the Plexus Group. The Plexus Group is a widely recognized consulting firm that works with institutional investors to monitor and reduce their equity trading costs. Their clients manage over $1.5 trillion in equity assets, and the firm has access to trading records covering approximately 25% of U.S. marketplace volume. Plexus clients include The Vanguard Group, State Street Global, and Alliance Capital Management. 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 (1999), and Conrad et al. (1997).

The data employed here include all Plexus client equity trades in NYSE-listed stocks within 100 trading days of the NYSE change to sixteenths. We also have data on Plexus client trades in Nasdaq stocks, and in an earlier draft we also examined the impact of the analogous Nasdaq move to sixteenths, which took place on June 2, 1997. The results are generally similar, but the Nasdaq test is much less powerful for three reasons. First, Nasdaq stocks under $10 were already quoted in sixteenths, and were unaffected by the tick size reduction (see, for example, Bessembinder, 1997). Second, prior to June 1997, Nasdaq transactions could take place on sixteenths or even finer increments. Transaction prices were thus relatively unaffected by the change to sixteenths. Third and perhaps most important, the move to sixteenths occurred as Nasdaq was in the process of implementing new order handling rules mandated by the SEC (see, e.g., Barclay et al., 1999), confounding any analysis of firms that implemented the new rules and sixteenths around the same time. In addition, as pointed out by a referee, Nasdaq does not enforce time priority, as market makers routinely execute orders by simply matching the inside quote. The arguments regarding tick size and liquidity supply are typically applied to markets such as the NYSE that are more likely to enforce time priority. Due to these characteristics of the Nasdaq market, we focus our attention on the NYSE event.

For each Plexus client order, the data record the date and time the order is released to a firm's trading desk, the volume-weighted average execution price reported by each executing broker, and any commissions paid. This information allows us to measure implementation costs and the sum of implementation costs and commissions, which we refer to as 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 midpoint of the prevailing quote at the time the order was released.

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

Our sample contains 386,487 orders executed for Plexus clients in 1,271 NYSE stocks. These stocks are a subset of the 1,690 TAQ firms analyzed earlier. To be included in the sample, a stock must be traded by at least one Plexus client in both the eighths and sixteenths period. Filters remove a small number of Plexus orders that appear to have incorrectly reported execution prices, since they are executed at prices outside the range of transaction prices observed in the TAQ data that day.

Table 1 also presents summary statistics on these orders. Plexus clients in our sample account for a substantial fraction of trading volume. The Plexus sample reflects about 13% of the total trading activity in the relevant NYSE stocks. The average Plexus order of 25,129 shares is over 13 times as large as the market-wide average trade of 1,855 shares, where both averages are calculated pre-event. However, it is important to note that Plexus order sizes and TAQ trade sizes are not directly comparable. The Plexus data consist of orders. These orders may be sent to brokers in multiple pieces, and executing brokers may not represent all of the trading interest at once. In short, one Plexus order may be executed in one trade or in several constituent trades. Unfortunately, Plexus does not collect data on the individual constituent trades.

Since quoted depth is a readily available source of liquidity, we also compare Plexus order sizes to depth at the inside quote. The Plexus data specify the time at which an order is released to the institution's trading desk, so we can use TAQ data to determine the quoted depth prevailing at that time on the relevant side of the market. That is, we measure bid depth prevailing when a Plexus client releases a sell order to its trading desk, and we measure prevailing ask depth at the time a Plexus client releases a buy order. Averaging across all Plexus client order releases, the mean prevailing quoted depth is 6,125 shares. The average Plexus order of 25,129 shares is more than four times this average prevailing depth. In fact, Plexus client orders are almost always bigger than the prevailing quoted depth. Before the advent of sixteenths, orders that exceed the prevailing quoted depth account for 93.94% of Plexus client volume. Orders that are at least 100 times the prevailing quoted depth account for 34.34% of Plexus client volume. These fractions are even higher post-event, measuring 95.94% and 41.96%, respectively, because quoted depths fall. These numbers emphasize that, for these institutions, liquidity demands usually exceed quoted depth, and thus quoted spreads are not likely to be a sufficient statistic for implementation costs.

Table 4 presents an initial look at the Plexus trading cost data before and after the June 24, 1997 change to sixteenths. Since implementation costs and total costs yield essentially identical conclusions, we focus on total costs. The sample is also partitioned based on order size and on quoted spread. All reported average costs are expressed in basis points and weighted by dollar volume to reflect the proportional costs of trading a representative Plexus client portfolio.

Table 4
Institutional trading costs around the NYSE move to sixteenths

The sample includes Plexus client trades in NYSE stocks within 100 trading days of the June 1997 adoption of sixteenths. Implementation cost is the difference between the transaction price and the price prevailing at the time the order was released to the trading desk, expressed in basis points. Total cost equals implementation cost plus commissions, and is also expressed in basis points. Presented figures are averages over time of dollar volume-weighted daily averages across firms within each specified grouping. Tests of significance are calculated assuming independence across firm-days. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively.

	Implementation costs			Total costs			
	Before	After	Change	Before	After	Change	Observations
All trades	55.5	74.4	+ 18.9**	68.2	85.4	+ 17.2**	386,487
Order size categories (shares)							
Less than 1,000	7.1	3.5	− 3.6**	17.7	11.1	− 6.6***	144,025
1,000 to 9,999	15.1	14.7	− 0.4	23.7	22.4	− 1.3	147,505
10,000 to 99,999	24.9	28.3	+ 3.4*	36.8	38.9	+ 2.1	74,922
More than 99,999	71.9	95.8	+ 23.9**	85.4	107.3	+ 21.9**	20,035
Spread quartiles							
1 Lowest	49.0	69.0	+ 20.0**	63.5	81.5	+ 18.0*	145,112
2	55.7	82.9	+ 27.2**	68.0	93.9	+ 25.9**	118,130
3	62.3	82.1	+ 19.8	72.9	91.3	+ 18.4**	79,575
4 Highest	71.4	54.9	− 16.5	81.3	62.9	− 18.4	43,670

Standard errors used in statistical tests are calculated assuming independence across firms and across days. The average correlation in execution costs across pairs of firms is 0.0007, indicating that cross-sectional independence is a very reasonable assumption.

Table 4 reports average institutional execution costs for NYSE stocks before and after June 24, 1997. Note first how little it costs institutions to have a modest order filled. For orders between 1,000 and 9,999 shares, one-way implementation costs average 15 basis points. This level is much lower than the corresponding one-way effective spread of 30 to 40 basis points based on the TAQ data shown in Table 3. On the other hand, large orders are much more costly for institutions to complete. Before sixteenths, Plexus client orders of at least 100,000 shares incurred implementation costs of 71.9 basis points. The corresponding one-way effective spread measure from Table 3 is 44.5 basis points.[5]

Turning to the tick size event, there are three notable features in the Plexus data. First, sixteenths are associated with a substantial increase in execution costs for these institutions. Second, the cost increases are concentrated in large orders. Third, the increase is most pronounced for firms with smaller spreads.

For the institutions in this sample, total one-way costs for NYSE orders, including commissions, increased from 68.2 basis points before the tick size change to 85.4 basis points afterward, an increase of about 25%. There is substantial variation across order sizes. For orders of less than 1,000 shares, there is a reduction from 17.7 basis points to 11.1 basis points after the tick size change. For orders over 100,000 shares, there is a 20% increase in costs from 85.4 basis points to 107.3 basis points. The overall figure is clearly driven by the larger trades. This reflects the fact that, 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 substantially increased execution costs.

Finally, the cost increase is found only in firms with smaller quoted dollar spreads. For example, total execution costs for firms in the smallest three spread quartiles increase by 18.0, 25.9, and 18.4 basis points, respectively. In contrast, firms with the largest spreads show no reliable evidence of a change in execution costs after June 24, 1997.

The results for large orders suggest that there is a reduction in liquidity associated with the change to sixteenths. We explore this possibility further in Table 5 by partitioning the data in a number of ways. The first partition is based on the institution's trading style. The Plexus data characterize the manager submitting orders as belonging to one of three trading styles: momentum, value, or indexing. Momentum traders tend to establish their trading positions

[5] It is worth noting that, though we have made the comparison here, Plexus order size categories are not directly comparable to TAQ trade size categories. As described earlier, a single Plexus order may be filled in one trade or in several constituent trades.

Table 5
Trading costs by manager style and worked vs. not worked status

The sample includes Plexus client trades in NYSE stocks within 100 trading days of the June 1997 adoption of sixteenths. Management style is classified by Plexus as momentum, value, or index. Orders are assumed to be worked if they are executed by multiple brokers or on multiple days; all other orders are considered not worked. Implementation cost is the difference between the transaction price and the price prevailing at the time the order was released to the trading desk, expressed in basis points. Total cost equals implementation cost plus commissions, and is also expressed in basis points. Presented figures are pooled dollar volume-weighted averages within each specified grouping. Tests of significance are calculated assuming independence across firm-days. Significance at the 1% level is denoted by ***.

	Implementation costs			Total costs			
	Before	After	Change	Before	After	Change	Observations
Management style							
Momentum	108.4	142.3	+ 33.9***	120.6	151.7	+ 31.1***	67,937
Value	12.8	37.9	+ 25.1	26.9	49.6	+ 22.7	60,643
Index	38.3	45.5	+ 7.2	50.6	56.6	+ 6.0	257,907
Orders not worked	46.9	77.0	+ 30.1***	59.7	88.4	+ 28.7***	333,651
Orders worked	64.2	56.4	− 7.8	76.9	71.0	− 5.9	52,836

quickly. As a result, they consume more of the available liquidity at any point in time, and they generally pay more to establish positions. Consistent with this intuition, Keim and Madhavan (1997) find that execution costs are higher for momentum traders.

Table 5 reports execution costs by manager style, both pre- and post-sixteenths. As found in earlier studies, execution costs for momentum traders in this sample are much greater than execution costs for either value managers or indexers. For example, before sixteenths, total one-way costs are 120.6 basis points for momentum traders, as compared to 26.9 basis points for value managers and 50.6 basis points for indexers. More importantly, sixteenths affect momentum traders more than other styles. On average, momentum traders pay 31.1 basis points more under sixteenths. Other styles experience no discernible change in their NYSE execution costs.

Another potential difference across orders is how a trading desk decides to execute an order. Our data allow us to identify orders that are executed over more than one day or executed by more than one broker. If either of these conditions hold, we classify the order as a worked order, since it is certain that these orders are executed in more than one trade. Other orders are classified as "not worked." This classification is not completely accurate, since some orders classified as "not worked" are no doubt executed by a single floor broker in multiple transactions over the course of a day. As noted earlier, the Plexus data do not provide information on the individual trades transacted to fill an order. These data restrictions force a second-best partition of the data.

We notice that worked orders are generally larger, and conversations with institutional traders indicate that orders are more likely to be worked in difficult market conditions. This observation suggests that worked orders should have higher costs. However, the trading desk will only work those orders where fast executions are not vital.

The evidence so far indicates that the reduction in tick size leads to a reduced willingness to provide immediacy. Perhaps liquidity providers are less willing to make such commitments if floor traders can easily step in front of limit orders or other explicitly stated and exposed trading interests by just slightly improving upon the stated price. This scenario does not imply, however, that those providing liquidity now begin to demand liquidity. Most likely, they monitor trading activity more closely and provide liquidity more cautiously. The liquidity provided is not likely to be available to those with urgent trading demands, but is still likely to be available to more patient traders. For this reason, we expect that "not worked" orders might suffer more under sixteenths because they demand immediacy, while worked orders may not be much more costly to execute with a narrower tick size.

Table 5 presents the change in execution costs for worked and not-worked orders. The total cost of orders that are not worked increases from 59.7 basis points before the advent of sixteenths to 88.4 basis points afterward, an increase of over one-third. There is virtually no change in the average cost for worked orders, which is consistent with our explanation if these orders do not demand immediacy.

4. Regression analysis

To this point, our analysis has been largely descriptive. We have separately controlled for manager style and whether an order is worked. We have also crudely controlled for order size and a firm's average quoted spread. We have not otherwise taken into account market conditions or the mix of stocks being traded. Perhaps traders trade more in less liquid stocks after the tick size change. Furthermore, the size partitions may not adequately control for the relation between order size and execution costs. 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.

The simplest approach to controlling for order, manager, and market characteristics would be a regression of the form

$$C_j = \alpha_0 + \alpha_1 D_j + X_j \beta + \varepsilon_j, \tag{1}$$

where C_j is the cost of executing order j, D_j is an indicator equal to one if order j is released after sixteenths are adopted, and X_j is a vector of control variables associated with order j. We employed this approach in a previous draft of this paper. However, the results in Tables 4 and 5 suggest that α_1, the coefficient of interest, is not constant across all types of orders. If the liquidity environment has changed in a more complex manner, with some orders benefiting and others doing worse, another specification is required.

Our solution is to fit execution costs to order, manager, and market characteristics, and then compare pre-sixteenths and post-sixteenths residuals. Specifically, we run firm-by-firm regressions using only pre-sixteenths orders, regressing the total execution costs of an order on a vector of order and manager characteristics. In order to have sufficient degrees of freedom, we arbitrarily require that each firm have at least 100 orders in the pre-sixteenths sample period. We use these pre-sixteenths regression coefficients to calculate residuals for both pre-event and post-event orders. These residuals are then averaged using dollar-volume weights. The difference between average pre-event and post-event residuals measures the proportional cost or benefit to a representative institutional portfolio of the move to sixteenths.[6]

If there is no change in the trading environment, then the residuals should be distributed identically in the pre- and post-sixteenths trading periods. In the pre-sixteenths period, the OLS moment conditions require that the average residual be zero. However, when these residuals are weighted by dollar volume of the associated order, the average residual generally differs from zero. Therefore, we focus on the change in the dollar volume-weighted average residual across the event.

More precisely, define C_{ij}^{PRE} as the total cost of executing the jth pre-sixteenths order in firm i. We postulate that

$$C_{ij}^{PRE} = X_{ij}\beta_i + \varepsilon_{ij}, \tag{2}$$

where X_{ij} is the row vector of control variables associated with order j in firm i, including an intercept, and the coefficient vector β_i can differ across firms. We estimate each firm separately using OLS and define the trading cost residual for any pre-sixteenths order j in firm i as

$$e_{ij}^{PRE} = C_{ij}^{PRE} - X_{ij}\hat{\beta}_i. \tag{3}$$

[6] This approach is similar in spirit to matching orders in the pre- and post-sixteenths trading periods based on a set of matching characteristics, and then looking at the dollar-weighted change in execution costs. However, given the large number of matching characteristics relative to the number of observations, that approach is not feasible for this study.

We also use the same coefficient vector to calculate the trading cost residual for post-event orders, such that

$$e_{ij}^{POST} = C_{ij}^{POST} - X_{ij}\hat{\beta}_i, \tag{4}$$

where C_{ij}^{POST} is the total cost in basis points of executing the jth post-event order in firm i. We then measure the dollar volume-weighted change in trading costs after controls. That is, we measure the weighted average change in execution costs as

$$\Delta C = \frac{\sum_{i,j} w_{ij}^{POST} e_{ij}^{POST}}{\sum_{i,j} w_{ij}^{POST}} - \frac{\sum_{i,j} w_{ij}^{PRE} e_{ij}^{PRE}}{\sum_{i,j} w_{ij}^{PRE}}, \tag{5}$$

where w_{ij}^{PRE} is the dollar volume of the jth pre-sixteenths order in firm i, and w_{ij}^{POST} is defined similarly.

To conduct inference, define $\bar{e}_{ik}$ as the dollar volume-weighted average of all trading cost residuals e_{ij} in firm i that take place on event day k. Event day zero is the first day of trading on sixteenths. Let v_{ik} be the total dollar volume of Plexus client orders in firm i on day k. Then we can rewrite Eq. (5) as

$$\Delta C = \frac{\sum_{i,k \geqslant 0} v_{ik}\bar{e}_{ik}}{\sum_{i,k \geqslant 0} v_{ik}} - \frac{\sum_{i,k<0} v_{ik}\bar{e}_{ik}}{\sum_{i,k<0} v_{ik}}. \tag{6}$$

We assume that firm-day $\bar{e}_{ik}$'s are all independent, and test the hypothesis that $\Delta C = 0$ using a two-sample equality of means test with weights v_{ik}.

The control variables in the regression equation reflect market and order characteristics. The variable *BUY* is equal to one if an order is a buy order and zero otherwise. This variable captures the fact that buy orders tend to be cheaper to execute than sell orders. *MKTVOL* is the NYSE trading volume on the day prior to the release of an order to the trading desk, measured in billions of dollars. It accounts for the possibility that orders are easier to execute when there is substantial trading activity in the market, other things being equal. *OSIZE* is the log of the order size in shares. Larger orders tend to be more costly to execute, and the coefficient on *OSIZE* should be positive. *STYLE-M* is equal to one if an order is placed by a momentum manager, and zero otherwise. *STYLE-V* is equal to one if an order is placed by a value manager, and zero otherwise. The regression also has an intercept, so there is no separate indicator variable for index traders. These indicator variables reflect the cost differential incurred by momentum and value traders relative to index traders. We expect the coefficient on momentum to be positive, since momentum traders are relatively impatient. Conversely, we expect the coefficient on value traders to be negative, since they are the most patient traders. *MOMEN* is the return over the two trading days prior to the day an order is released, multiplied by -1 if an order is a sell. This variable captures the effects of recent price moves on execution costs. *IPRICE* is the inverse of the closing mid-quote price on the day prior to the release of an order to the trading desk. If there are fixed costs of trading that are independent of the amount traded, higher priced stocks should be cheaper to trade, other things being equal, and the coefficient on *IPRICE* should be positive. The last variable is *RANGE*, which is the difference between the highest and lowest mid-quote prices on the day before an order is released to the trading desk divided by the mid-quote price at the close of trading that day. *RANGE* captures the effects of within-firm time series changes in volatility on execution costs. Since executions are thought to be more difficult during volatile markets, the coefficient on *RANGE* is expected to be positive.

A number of articles have used variables similar to those chosen here. In particular, Keim and Madhavan (1997) employ similar controls in their study using similar data. The variable *RANGE* was used in Bollen and Whaley (1998) to control for changes in volatility. Analyses by the Plexus Group indicate the importance of momentum as a determinant of execution costs.

The benchmark pre-sixteenths regressions are presented in Table 6. In addition, the regression for the post-sixteenths period is presented in order to identify changes in the determinants of execution costs. The table contains the means and medians of the coefficient estimates from the firm-by-firm regressions, along with the average adjusted R-squared, the number of firms, and the number of observations. Note that requiring at least 100 observations in the benchmark time period reduces the number of firms included in our analysis by about one half, though the analysis still includes over 84% of the orders analyzed earlier in the paper. Inference is conducted using standard t-tests for cross-sectional means and Wilcoxon signed rank tests for cross-sectional medians. All of the variables are significant and of the expected sign with the exception of *MOMEN* and *RANGE*, neither of which is significant in the benchmark regression. Furthermore, the coefficients are generally similar to those in Keim and Madhavan (1997).

The statistical tests focus on changes in the regression residuals, but a comparison of the coefficients in the pre- and post-sixteenths time periods suggests a number of changes in the market. First, the mean coefficient on *OSIZE* increases from 5.78 to 7.03, reflecting an increased cost to placing larger orders.

Second, there appears to be an increase in the costs incurred by momentum traders and value traders relative to index traders. As shown in Table 6, the mean of *STYLE-M* increases from 7.60 pre-sixteenths to 13.51 post-sixteenths. The increase in the cost of momentum trades is consistent with our earlier results. A related result is that the coefficient on *MOMEN* is significant and positive in the post-sixteenths regression, but insignificant in the benchmark regression. That is, the presence of adverse momentum affects execution costs after the change to sixteenths, but not before the change. This evidence is consistent with our general hypothesis that the change to sixteenths has reduced the amount of liquidity available in the market.

Table 7 presents our first analysis of the change in trading cost residuals for orders in NYSE-listed stocks. The change is given for all firms, by order size

Table 6
Determinants of NYSE trading costs

Cross-sectional means and medians of the coefficients in the following regression for each firm:

$$C_i = \alpha_0 + \alpha_1 BUY_i + \alpha_2 MKTVOL_i + \alpha_3 \log(OSIZE_i) + \alpha_4 STYLEM_i + \alpha_5 STYLEV_i + \alpha_6 MOMEN_i + \alpha_7 IPRICE_i + \alpha_8 RANGE_i + \varepsilon_i,$$

where the dependent variable is the total cost of order i in basis points, BUY is a dummy variable equal to one if the Plexus client purchased shares, $MKTVOL$ is the total $NYSE$ volume, in millions of dollars, on the day before the order was released, $OSIZE$ is the size of the order in shares, $STYLEM$ and $STYLEV$ are indicators equal to one if the order was placed by a manager that pursues momentum or value trading objectives, respectively, $MOMEN$ is adverse momentum measured by the two-day return prior to the day the order is released, multiplied by -1 for sell orders, $IPRICE$ is the inverse of the price at the close of trading on the day prior to the release of the order, and $RANGE$ is the proportional difference between the high and low price of a stock during the day prior to the order release. A firm is included only if there are at least 100 trades by Plexus clients in the pre-sixteenth trading period. The benchmark regression uses pre-sixteenths data only. Inference is conducted using standard t-tests for means and Wilcoxon signed rank tests for medians. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively.

	Benchmark		Post-sixteenths	
	Mean	Median	Mean	Median
Intercept	19.66	16.67	− 1.93	− 9.03
BUY	− 76.22***	− 56.91***	− 67.00***	− 53.94***
MKTVOL (billions)	− 0.10**	− 0.01***	− 0.06**	− 0.01**
OSIZE	5.78***	4.42***	7.03***	6.16***
STYLE-M	7.60***	3.73***	13.51***	10.01***
STYLE-V	− 5.47**	− 4.44***	− 0.04	− 1.64
MOMEN	− 23.04	3.80	166.69***	129.81***
IPRICE	755.40*	839.98***	8.47	0.00
RANGE	− 18.68	16.57	57.48	0.00
Number of firms	538		538	
Number of orders	160,778		165,020	
Avg. $\bar{R}^2$	16.25%		18.38%	

category, by spread quartile, and for combinations of order size and spread. Immediately below each change is the number of firm-days for which there is a relevant Plexus client trade. Recall that we assume that execution costs are independent across firms and across days, so the number of firm-days can be thought of as the number of independent observations in the sample.[7] We also

[7] We test this assumption by calculating the average correlation of the daily time series of execution costs between pairs of firms. The average pairwise correlation is 0.0009, indicating that cross-sectional independence is a very reasonable assumption.

Table 7
Changes in NYSE trading costs using regression controls by spread and order size partitions

Changes in trading costs from the pre-sixteenths to post-sixteenths sample period after controlling for order characteristics and market conditions that are known to affect trading costs. Specifically, the reported value is the change in the dollar-weighted average trading cost residual following the adoption of sixteenths. The trading cost residual is the difference between the realized total cost of an order and the expected total cost of an order, where the expected total cost is determined using the firm-by-firm benchmark pre-sixteenths regression in Table 6. This represents the average change in trading costs, in basis points, for each dollar traded by Plexus clients, after controlling for order characteristics and market conditions. Beneath each change in trading costs is the number of firm-days in each subsample. Tests of significance assume independence across firm-days. The third number in the partitions by order size is the percentage of total dollar volume in the given column. Total volume figures are for the entire sample, using both pre-sixteenths and post-sixteenths data. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively.

		Spread quartiles			
	All firms	1 (Smallest)	2	3	4 (Largest)
All orders					
Change in cost	+ 22.5***	+25.8***	+28.2***	+ 23.1***	−17.9***
Number of firm-days	97,016	32,047	31,179	23,486	10,309
Number of firms	538	176	170	132	60
Total volume (millions)	$356,802	$179,634	$99,263	$52,208	$25,697
Orders of less than 1,000 shares					
Change in cost	− 1.9***	− 5.1***	+ 0.3	− 0.2	− 2.4
Number of firm-days	69,422	22,764	22,399	17,065	7,194
Fraction of column volume	0.7%	0.5%	0.7%	1.1%	1.1%
Orders of 1,000 to 9,999 shares					
Change in cost	+ 0.5	− 1.5	+ 0.6	+ 1.4	+ 5.2
Number of firm-days	64,225	23,156	21,154	14,178	5,734
Fraction of column volume	5.4%	4.5%	5.3%	6.9%	7.4%
Orders of 10,000 to 99,999 shares					
Change in cost	+ 4.5***	+ 3.3*	+ 8.7***	+ 6.9**	− 6.2
Number of firm-days	40,398	15,782	12,692	8,111	3,813
Fraction of column volume	25.5%	21.8%	24.3%	30.7%	38.3%
Orders of 100,000 shares or more					
Change in cost	+ 28.4***	+ 32.4***	+ 33.9***	+ 27.8**	− 29.0
Number of firm-days	13,974	6,498	4,571	2,066	839
Fraction of column volume	68.4%	73.2%	69.7%	61.3%	52.9%

report the number of firms and dollar volume for the whole sample and spread quartiles so that the relative trading activity in each spread quartile can be evaluated. Similarly, we report the percentage of dollar trading volume associated with each size partition.

Across all firms, average execution costs increase by 22.5 basis points. Costs increase for all firms except those with the largest spreads, consistent with the evidence in Table 4. About half the dollar volume takes place in firms in the smallest spread quartile. For that quartile, execution costs rise by almost 26 basis points. More importantly, the change in execution costs increases monotonically in order size. For example, execution costs are 1.9 basis points cheaper under sixteenths for orders less than 1,000 shares. On average, the largest orders of at least 100,000 shares cost 28.4 basis points more once sixteenths are adopted.

The table also reveals that small orders constitute only 0.7% of Plexus client volume, while the largest orders account for over 68% of dollar volume. This finding is true even though there are many more small-order firm-days. For the smallest orders, changes in costs are probably driven by the reductions in bid–ask spreads.

This clear pattern across order sizes does not extend to firms in the largest spread quartile. In fact, for these firms, sixteenths have no discernible effect on either large or small orders. At first glance, this observation seems to have a simple explanation. Specifically, when the tick size at the inside quote is not binding, it might be more difficult to discern the effects of a tick size reduction. Nevertheless, we would still expect an increase in the ability of traders on the floor, including the specialist, to step ahead of the book by offering price improvement of 1/16 rather than 1/8. Thus, one interpretation is that stepping in front of the book is not an empirically important activity. Another possibility is that these institutions are as likely to benefit as they are to be hurt. For example, a floor broker might take the institution's order and step in front of the book. On the other hand, there are far fewer observations in the largest spread quartile. The results for this quartile may simply be due to low power.

Table 8 extends our analysis of changes in NYSE execution costs by looking at the change in costs for various manager styles and within trade categories for each manager. The organization of the table is similar to Table 7, except that we omit the percentage trading activity associated with each trade size category because they are virtually identical to those in Table 7. For momentum managers, execution costs increase by over 40 basis points, an increase of about one-third. Once again, cost changes are increasing in order size and are driven by the largest orders of 100,000 shares or more, which are 45.5 basis points more expensive under sixteenths.

The situation is qualitatively similar for value managers. Overall, they experience an increase in execution costs of 25 basis points, and this overall increase is driven by the biggest orders, which cost 35.6 basis points more in the post-event period. Index managers see a more modest increase in execution costs of about 9 basis points.

We finish our analysis by comparing worked orders to other orders using the regression approach. These results are presented in Table 9. Both worked and

Table 8
Changes in NYSE trading costs using regression controls by manager style partitions

Changes in trading costs from the pre-sixteenths to post-sixteenths sample period after controlling for order characteristics and market conditions that are known to affect trading costs. Specifically, the reported value is the change in the dollar-weighted average trading cost residual following the adoption of sixteenths. The trading cost residual is the difference between the realized total cost of an order and the expected total cost of an order, where the expected total cost is determined using the firm-by-firm benchmark pre-sixteenths regression in Table 6. The reported value represents the average change in trading costs, in basis points, for each dollar traded by Plexus clients, after controlling for order characteristics and market conditions. Beneath each change is the number of firm-days in each subsample. Tests of significance assume independence across firm-days. Total volume figures are for the entire sample, both pre-sixteenths and post-sixteenths. Significance at the 1%, 5%, and 10% levels is denoted by ***, **, and *, respectively.

	Manager style		
	Momentum	Index	Value
All Orders			
Change in cost	+ 40.7***	+ 9.3***	+ 25.0***
Number of firm-days	37,140	88,638	37,514
Total volume ($ millions)	$125,097	$177,980	$80,902
Orders of less than 1,000 shares			
Change in cost	− 0.1	− 2.5***	− 0.8
Number of firm-days	17,639	58,771	16,654
Orders of 1,000 to 9,999 shares			
Change in cost	+ 1.0	+ 1.1	− 2.1
Number of firm-days	14,474	52,137	17,059
Orders of 10,000 to 99,999 shares			
Change in cost	+ 4.5*	+ 5.4***	+ 1.9
Number of firm-days	10,262	26,776	11,674
Orders of 100,000 shares or more			
Change in cost	+ 45.5***	+ 10.3*	+ 35.6***
Number of firm-days	4,555	7,419	3,477

non-worked orders are more costly to execute under sixteenths, but the effect is bigger for non-worked orders, with an increase of 32.9 basis points, as compared to an increase of 12.1 basis points for worked orders.

If sixteenths make it more costly to execute a given order without working it, one might expect traders to work more orders. They do. Table 9 reports a significant increase in the proportion of worked orders, from 46.6% of volume pre-sixteenths to 49.6% post-sixteenths. This result provides evidence that institutions respond to the changed environment under sixteenths by working

Table 9
Worked and not-worked orders

Changes in trading costs from the pre-sixteenths to post-sixteenths sample period after controlling for order characteristics and market conditions that are known to affect trading costs. Specifically, the reported value is the change in the dollar-weighted average trading cost residual following the adoption of sixteenths. The trading cost residual is the difference between the realized total cost of an order and the expected total cost of an order, where the expected total cost is determined using the firm-by-firm benchmark pre-sixteenths regression in Table 6. This value represents the average change in trading costs, in basis points, for each dollar traded by Plexus clients, after controlling for order characteristics and market conditions. Beneath each change is the number of firm-days in each subsample. Tests of significance assume independence across firm-days. Total volume figures are for the entire sample, both pre-sixteenths and post-sixteenths. Significance at the 1% level is denoted by ***.

Worked orders	
Change in costs	+ 12.1***
Number of firm-days	31,579
Total volume ($ millions)	$201,995
Not-worked orders	
Change in costs	+ 32.9***
Number of firm-days	94,609
Total volume ($ millions)	$181,984
Proportion of orders worked (%)	
By shares traded	
Before	46.6
After	49.6
Change	+ 3.0***

more orders, and it suggests that institutions must trade more patiently when the tick size is smaller.

5. Discussion and conclusions

The evidence presented here implies that institutional trading costs increase with the adoption of sixteenths by the NYSE. In particular, those who demand liquidity most aggressively are affected most. This evidence complements that of Goldstein and Kavajecz (2000), who find that there is less liquidity provision after the NYSE adoption of sixteenths, as measured by a reconstruction of the limit order book. They find that sixteenths reduce depth throughout the book. However, the book is only a fraction of total liquidity supplied. Harris and Hasbrouck (1996) and Lipson (1999), using samples from two different time periods, both find that only about one quarter of NYSE executed volume is executed against the limit order book. Specialists and the floor account for much of the additional liquidity supply.

When Goldstein and Kavajecz (2000) consider the additional sources of liquidity by measuring effective spreads, they and others find that effective spreads are also usually lower post-event, even for large trades, at least in high volume stocks. This suggests that the specialist and the floor are stepping up or stepping in front of the book to provide liquidity, or that liquidity provision has migrated from the book to the floor. Because additional liquidity may be supplied by the floor, their evidence is still consistent with the standard conclusion that sixteenths reduce transaction costs on most trades.

Our results are quite different. The evidence here shows that institutions as a group pay more under sixteenths, and the data here highlight the importance of studying orders rather than trades. While the cost of individual trades of all sizes decline under sixteenths, execution costs are higher under sixteenths for all but the smallest institutional orders.

Not all orders are affected equally by the tick size change, though. In fact, many kinds of orders and institutions are essentially unaffected by the tick reduction. Perhaps our most striking finding is that liquidity demanders, particularly momentum traders and those submitting large orders, bear most of the increased costs.

There is also suggestive evidence that institutions break up trades more often post-sixteenths. For example, more institutional orders are worked (i.e., executed over multiple days or by multiple brokers) after the adoption of sixteenths. The average trade size from the TAQ data is lower post-sixteenths. Additional work using institutional data at the trade level might shed more light on this issue.

These findings are of considerable interest in light of recent theoretical work. For example, Glosten (1995) models the effect of price discreteness on market-makers, small traders, and large traders. His 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. In contrast, for plausible parameter values, Seppi (1997) predicts that a smaller tick size benefits small traders but is costly for large traders. Our evidence is consistent with the latter model but not with the former.

Alternatively, the evidence in this paper is consistent with the following, even simpler explanation. Assume that market-makers do not earn rents on average, either before or after sixteenths, but may be able to cross-subsidize between large and small orders. The tick size reduction causes spreads to fall. This reduces market-maker surplus on small orders. To make up this shortfall, market-makers must charge more for large orders and other orders that demand more liquidity, such as large momentum orders. Ronen and Weaver (1998) find that AMEX specialist profits are unaffected by the move to sixteenths, lending support to the idea of a simple transfer among investors.

Additional data are probably necessary to distinguish between these explanations. For example, detailed order data would be required to determine conclusively whether specialists, floor traders, or others are more likely to step in front of the book under sixteenths. We hope to interest others in these issues and explanations, and we leave any such investigations to future research.

Our results may also explain some earlier tick size findings. For example, when the Toronto Stock Exchange (TSE) adopted decimal pricing and reduced its minimum tick size in April 1996, the share of TSE order flow in NYSE-listed stocks did not increase (see Ahn et al., 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 execution costs for institutional traders, and this could explain the lack of change in TSE market share for cross-listed stocks.

The immediate lesson of this exercise is that traditional liquidity 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 execution costs. This observation has implications beyond the tick size controversy, and suggests that researchers should not rely exclusively on effective spreads as measures of liquidity.

As a group, are institutions truly worse off with a smaller minimum tick size? 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 unlikely that such benefits would outweigh the substantial increase in observed execution costs, and it seems reasonable to conclude that the institutions are worse off under sixteenths.

Based on this conclusion, the paper has potential 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. Of course, this transfer could simply be the end of a subsidy of institutional traders paid by small traders, if the large tick size kept spreads artificially wide. In any case, institutions appear to be losers, regardless of how the transfer is characterized. A smaller tick size does not appear to be pareto-improving. 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, our results indicate that the economics of liquidity provision are subtle, and a non-trivial tick size may enhance the supply of liquidity. The results also suggest that institutional traders should, as a group, regard skeptically any proposal for a further reduction in minimum price increments.

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