Eighths, Sixteenths and Market Depth: Changes in Tick Size and Liquidity Provision on the NYSE

Michael A. Goldstein* and Kenneth A. Kavajecz**

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* Assistant Professor of Finance
Finance Department
College of Business and Administration
University of Colorado at Boulder
Campus Box # 419
Boulder, Colorado 80309-0419
Ph: (303) 492-1242
Email: michael.goldstein@colorado.edu

**Assistant Professor of Finance
Finance Department
The Wharton School
University of Pennsylvania
2300 Steinberg Hall - Dietrich Hall
Philadelphia, PA 19104-6367
Ph: (215) 898-7543
Email: kavajecz@wharton.upenn.edu

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Abstract

We use limit order data provided by the New York Stock Exchange (NYSE) to investigate the impact of reducing the minimum tick size on the liquidity of the market. Specifically, we analyze both spreads and depths (quoted and on the limit order book) for periods before and after the NYSE's change from eighths to sixteenths. Similar to other studies, we find that quoted spreads and quoted depth declined after the change. However, we find that depth declined *throughout* the entire limit order book as well. The combined effect of smaller spreads and reduced cumulative depth in the limit order book has made liquidity demanders trading small orders better off while those trading large orders worse off. The benefit to the small orders occurs mostly in frequently traded stocks, while small orders in infrequently traded stocks see little, if any, benefit.

"Bids or offers in stocks above one dollar per share shall not be made at a less variation than 1/8 of one dollar per share; in stocks below one dollar but above ½ of one dollar per share, at a less variation than 1/16 of one dollar per share; in stocks below ½ of one dollar per share, at a less variation than 1/32 of one dollar per share ¼"

-- Rule 62, NYSE Constitution and Rules, May 1997

"Bids or offers in securities admitted to trading on the Exchange may be made in such variations as the Exchange shall from time to time determine and make known to its membership."

-- Rule 62, NYSE Constitution and Rules, July 1997

On June 24, 1997 the New York Stock Exchange (NYSE) reduced the minimum price variation for quoting and trading stocks from an eighth to a sixteenth, marking the first time in the 205 year history of the exchange that the minimum price variation had been altered. This minimum price variation, often referred to as tick size, implies that both quoted and transaction prices must be stated in terms of this basic unit. By cutting the tick size in half, the NYSE adopted a finer price grid, causing the universe of realizable quoting and trading prices to double overnight.

The move by the NYSE was the latest in a series of tick size reductions, including reductions by Nasdaq, the American Stock Exchange (AMEX) and the regional exchanges.[1] Despite these recent reductions, the appropriateness and effects of changes in tick size remain open to debate. Some, such as Hart (1993), Peake (1995), O'Connell (1997), and Ricker (1998), argue that smaller tick sizes benefit liquidity demanders as competition between liquidity providers is likely to force a reduction in the bid-ask spread. Others, such as Grossman and Miller (1988) and Harris (1997), argue that while such a change may benefit some liquidity *demanders*, it may damage liquidity *providers*, as it could increase their costs and thus decrease their willingness to provide liquidity. As Harris (1997) notes, the tick size effectively sets the minimum bid-ask spread that can be quoted and thus helps determine the profitability

[1] The recent changes in tick size were partially brought about by the introduction of the Common Cents Stock Pricing Act of 1997 (H.R. 1053) into the U.S. Congress. Although it did not contain a restriction on the minimum tick size, H.R. 1053 called for U.S. equity markets to quote prices in terms of dollars and cents.

of supplying liquidity. Consequently, changes in the tick size have important implications for the quoted spread, the supply of liquidity, trading by specialists and floor brokers, and order submission strategies (including market versus limit order placement, limit order prices and trade size). The interactions among these changes are dynamic, not static, and may produce aggregate effects that increase, rather than decrease, transaction costs.

Unlike previous studies that focused primarily on changes in the quoted bid-ask spread and the quoted depth, our focus is how NYSE liquidity providers have been affected by the change in tick size and what these changes imply about the transactions costs faced by market participants.[2] The response of liquidity providers to a reduction in the minimum tick size and its impact on spreads and depths is uncertain. One possible response is that while liquidity providers provide less depth at the new, narrower quoted spread, they may continue to provide the same liquidity at the previous prices. While the depth at the quoted spread will be reduced, the cumulative depth at a certain price – defined as the sum of the depth for all limit orders up to and including that price – will remain unaffected.[3] Alternatively, liquidity providers may shift their limit orders to prices further from the quotes, or – if the costs to liquidity providers sufficiently increase – choose to leave the market altogether. As a result, the number of liquidity providers could decrease overall, causing not only the depth at the quoted bid and ask to decline, but the cumulative depth to decline as well.[4] Thus, while order sizes smaller than the quoted depth may benefit from the reduction in spreads, larger sized orders may become more expensive as they may be forced to "eat into" the limit order book to find sufficient

[2] Liquidity on the floor of the NYSE is provided by limit order traders as well as floor brokers and specialists (see Sofianos and Werner (1997)). Investors who place orders in the limit order book provide liquidity by publicly stating the amount that they are willing to trade at a certain price, while NYSE floor brokers provide liquidity by working orders that may or may not be displayed to the general market. The specialist may supply additional liquidity by choosing to improve upon the limit order book and/or floor broker interest either by improving the price or by displaying more depth.

[3] Cumulative depth at a certain price is calculated by adding up all of the shares available at that price or better. For example, if there are 200 shares offered at 20, 300 shares offered at 20 1/16, and 600 shares at 20 1/8, the cumulative depth at 20 1/16 is 500 shares and the cumulative depth at 20 1/8 is 1,100.

[4] Studies considering only the posted quotes and depths are not able to evaluate whether liquidity provision has changed or remained constant. If spreads decrease, even measures that relate posted spreads to posted depths cannot determine if these newer spreads are caused by newer limit orders or a shift of limit orders closer to the quotes. Indeed, if such a shift occurred, such measures cannot tell if it was a uniform shift or if new limit orders have tightened the spread while other limit orders have left the book. Using the cumulative depth measure, we are able to answer exactly how this liquidity provision has changed.

liquidity. The question remains, therefore, whether the change in tick size will cause sufficient changes in the cumulative depth to increase costs for larger orders while still reducing costs for smaller ones.

As Lee, Mucklow and Ready (1993) note, any study of liquidity provision must examine the changes in both prices and depths. Moreover, Harris (1994) notes that to address properly whether or not liquidity has been enhanced or hampered requires an investigation into how the depth throughout the limit order book has been altered. Thus, in order to study the combined effects of change in the spread, depth at the market and cumulative depth, we use order data provided by the NYSE to reconstruct the limit order book before and after the change in tick size.[5]

Similar to previous studies, we find that quoted spreads have declined by an average of $0.03 or 14.3% and quoted depth declined by an average of 48%. However, unlike previous studies, we also find that limit order book spreads (i.e., the spread between the highest buy order and the lowest sell order) have actually *increased* by an average of $0.03 or 9.1% and depth at the best prices on the limit order book declined by 48%.

More important, we find that cumulative depth on the limit order book *declines* at limit order prices as far out as half a dollar from the quotes. In addition, NYSE floor members have also decreased the amount of liquidity they display, as measured by the difference at the current quote price between the depth on limit order book and the depth quoted by the specialist. However, this reduction in displayed additional depth by NYSE floor members is much less than the depth reduction on the limit order book.

Overall, we find that the cumulative effect of the changes in the limit order book and NYSE floor member behavior has reduced the cost for small market orders but increased the cost for larger market orders. The effect of the minimum tick size reduction is sensitive to the trade size and the trading frequency of each stock; the benefit to small orders is sharply reduced with the frequency of trading. Thus, in contrast to previous studies that found liquidity increases after tick size reductions, we find evidence of liquidity decreases for some market participants.

The remainder of the paper is organized as follows. Section I provides a review of the effects of tick size changes. Section II briefly describes the data set and procedure used in constructing the estimates of the limit order book. Section III details the impact of the minimum tick size on spreads, depths and the cost of transacting. Section IV describes the effects on various liquidity providers, while Section V discusses the effects of asymmetric information by comparing the effects on closed-end funds and trusts with the rest of our sample. Section VI concludes.

I. Effects of Tick Size Reductions

A number of papers examine the effects of reductions in tick size both theoretically and empirically. While several theoretical models consider the issue of optimal tick size, the most relevant to this study are Seppi (1997) and Harris (1994).[6] Seppi's model demonstrates that when the price grid is fine, the limit order book's cumulative depth decreases as the minimum tick size declines. Thus, although small traders prefer finer price grids while large traders prefer coarser ones, both groups agree that extremely coarse and extremely fine price grids are undesirable. Harris (1994) also makes a compelling argument that a reduction in tick size would reduce liquidity. For stocks where the tick size is binding, bid-ask spreads should equal the tick size with relatively high quoted depth, as specialists and limit order traders find liquidity provision a profitable enterprise. A reduction in tick size would reduce quoted spreads on constrained stocks but would also reduce quoted depth, due to a decrease in the marginal profitability of supplying liquidity. Harris further notes that the reduction in tick size would likely affect stocks even where the constraint is not binding: since the tick size represents the subsidy paid to liquidity providers, a reduction in that subsidy will alter the level and nature of the liquidity provided. Specifically, in the wake of a tick size reduction, liquidity providers may

[5] We thank the NYSE for the collection and provision of the data used in this study.

choose to reduce the number of shares they pledge at a given price, shift their shares to limit prices further from the quotes to recapture some of the lost profit, or if the liquidity provider is at the margin, exit the market altogether.

Empirical research on minimum tick size reductions of international and U.S. equity markets have tested and corroborated the predictions of Harris (1994) using quoted bid-ask spreads and quoted depths. Angel (1997), using international data to investigate the connection between minimum tick sizes and stock splits, argues that a small tick size increases liquidity by allowing for a small bid-ask spread; however, it also diminishes liquidity by making limit order traders and market makers more reticent to supply shares. Using data from the Stockholm Stock Exchange, Niemeyer and Sandås (1994) also corroborate the arguments in Harris (1994), showing that the tick size is positively related to the bid-ask spread and market depth, and negatively related to trading volume. Bacidore (1996), Ahn, Cao and Choe (1998), Huson, Kim and Mehrotra (1997) and Porter and Weaver (1997) study the impact of the April 15, 1996 Toronto Stock Exchange's (TSE) reduction in the minimum tick size to five cents. These studies found a significant decline in the quoted bid-ask spreads of 17.0% to 27.0% and in the quoted depth of 27.0% to 52.0% (depending on study and sample), while average trading volume displayed no statistically significant increase, generally confirming the predictions made by Harris (1994). The authors argue that the smaller tick size had at worst no effect and at best a liquidity improving effect on the TSE because of the dramatic decrease in spreads and despite the decrease in quoted depth.

Domestically, Crack (1994) and Ahn, Cao, and Choe (1996) assess the impact of the September 3, 1992 American Stock Exchange reduction in the minimum tick size for stocks priced under five dollars, finding approximately a 10% decline in quoted spreads and depths in addition to an increase in average daily

[6] In the theoretical literature, the optimal tick size hinges upon whether the model casts a minimum tick size as pure friction to the Bertrand competition of liquidity providers – as in Anshuman and Kalay (1998), Bernhardt and Hughson (1993), and Kandel and Marx (1996) – or whether a minimum tick size coordinates negotiation, as in Brown, Laux and Schacter (1991) and Cordella and Foucault (1996). A related literature debates the relation between tick size and payment-for-order flow. Chordia and Subrahmanyam (1995) develop a model where smaller tick sizes represent frictions that allow for enough slack to make payment for order flow a profitable strategy. In contrast, Battalio and Holden (1996) present a model that shows that movements toward smaller tick sizes will not eliminate payment for order flow arrangements.

trading volume of 45 to 55%. Bessembinder (1997) studies NASDAQ stocks whose price level breaches the ten dollar price level and thus changed tick size from eighths to sixteenths. His results show that for those stocks whose price level fell below the ten dollar level, the effective spread fell by eleven percent.

In research on more recent U.S. tick size reductions, Ronen and Weaver (1998) study the impact of the May 7, 1997 switch to sixteenths by the American Stock Exchange. Their results, conditioning the sample by price level and trading volume, are consistent with Harris (1994) as well as with other earlier empirical work. Their results on reduced quoted spreads and depth cause the authors to conclude that the implemented reduction to the minimum tick size has decreased transactions costs and increased liquidity.

Bollen and Whaley (1998) and Ricker (1998) conduct analyses of the minimum tick size reduction on the NYSE. Their results demonstrate that the volume weighted bid-ask spread declined by approximately $0.03 or 13% to 26% depending on the study. Furthermore, they find that quoted depth decreased between 38% and 45%. Collectively they conclude that the NYSE tick size reduction has improved the liquidity of the market especially for low priced shares. Pruitt, Van Ness and Van Ness (1998) also examine the impact of the tick size reduction on the NYSE, AMEX and NASDAQ. They find that on the NYSE quoted spreads and depths, volatility and average trade size all declined.

Finally, using institutional data, Jones and Lipson (1998) examine the effects of the change in tick size at the NYSE and on NASDAQ. Supporting the results in this study, they find that although trading costs decreased for smaller trades, they have increased for larger trades. Jones and Lipson argue that spreads alone are insufficient for measuring market quality due to these differential effects, and conclude that smaller tick sizes may not be pareto-improving.

II. Data and Methodology

Due to limitations on data availability, previous studies on tick size reductions have been confined to using trade and quote data, limiting the scope of their analyses. Using a new data set that contains system order submissions, executions and cancellations as well as quotes, this study examines the reactions of

different liquidity providers (both limit order traders and members on the NYSE floor) to examine and explain changes in their behavior related to changes in tick size.

Our investigation of the impact of the minimum tick reduction requires that we be able to assess depth away from the quote. Thus, our analysis requires knowledge of the limit order books that compete with the specialist and floor brokers to supply liquidity. Using SuperDOT order data provided by the NYSE, we reconstruct the limit order books using the technique described in Kavajecz (1998). The order data provides information about system order placements, executions and cancellations and is similar in nature to the Trades, Orders, Reports and Quotes (TORQ) data set previously released by the NYSE. Our sample consists of the 110 surviving TORQ stocks as of October 1997.[7] The ten closed-end funds or unit investment trusts in the sample are considered separately in section V since their limit order books are substantially different from the limit order books of the other stocks in the sample. The remaining 100 stocks are separated into quintiles with 20 stocks in each and are ranked by average daily trading volume as of December 1996.[8]

The principle behind the limit order book estimation is that at any instant in time, the limit order book should reflect those orders remaining after the orders placed prior to the time in question are netted with all prior execution and cancellation records. We first use data from March 1997 through November 1997 to search for all records that have order arrival dates prior to March. We use these good-'til-cancelled limit orders as an estimate of the initial limit order book just prior to March. We create "snapshots" of the limit order book by sequentially updating the limit order book estimates using records whose date and time stamp are previous to the time of the snapshot.

We generate limit order book estimates for three four-week sample periods, one period prior to the minimum tick reduction and two periods after the minimum tick reduction. The period prior to implementing

[7]The original TORQ data set is a stratified sample of 144 NYSE listed securities over the three months, November 1990 through January 1991. The surviving 100 firms are slightly over-weighted in the largest stocks but are nonetheless reasonably well-distributed across NYSE quintiles. For further information on the TORQ data set see Hasbrouck (1992) and Hasbrouck and Sosebee (1992).

[8]Rankings were also done using market capitalization as well as price level. The results presented in this paper are ranked by trading volume because Ahn, Cao, and Choe (1996), Porter and Weaver (1997) and Ronen and Weaver (1998) present evidence that trading volume is a better predictor of tick size effects than the other two sorting variables.

sixteenths, called the pre-reduction period, begins on May 27, 1997 and ends June 20, 1997. The first period after the tick reduction begins June 30, 1997 and ends July 25, 1997 and the second period after the tick reduction begins August 25, 1997 and ends September 19, 1997. The week of the change was eliminated to avoid any potential data errors associated with the actual switch. Two separate post-reduction periods are used to control for any transition period caused by market participants taking time to adjust their strategies to the new equilibrium. Since the data in the two post-reduction periods are both qualitatively and quantitatively similar, we aggregate them into a single period.

Limit order books are estimated at thirty minute intervals for each business day in the pre- and post-reduction periods that the NYSE was open. The result is a sequence of limit order books "snapshots" comprised of approximately 266 observations in the pre-reduction period and approximately 532 observations in the combined post-reduction period for each of the 110 stocks in the sample.[9] Results are equally-weighted averages across these thirty minute snapshots, either overall or by trading volume quintile.[10]

III. Spreads, Depths and the Cost of Transacting

Similar to other studies, we begin by documenting the effect that the tick reduction had on quoted spreads and quoted depth. Table I shows the quoted spreads and quoted depths results: Panel A displays the results for the pre-reduction period, Panel B displays the results for the post-reduction period, and Panel C displays the change. Consistent with the predictions of Harris (1994) and the empirical studies of other comparable tick size reductions, we find that the average quoted spread *decreased* by $0.03 or 14.3% and average quoted depth declined by 48.4%.[11] These changes are significant at the 1% level. Furthermore, the

[9] Estimates were calculated at the time of the opening quote and are calculated each half-hour on the half-hour thereafter. For example, if a stock opened at 9:40:28 AM, an estimate would be taken at that time and then estimates would be done at 10:00:00, 10:30:00, etc. The number of limit order books for each stock is approximate because occasional late openings (later than 10:00:00) causes differences in the number of estimates for each stock.

[10] One unusual stock in our sample deserves special comment. Although Allegeny (Ticker Symbol: Y) is a thinly-traded stock which puts it in the smallest quintile (quintile 5), its price at the end of December 1996 was over $200. During the pre-period of our study, the dollar quoted spread for Allegeny was $1.78 and during the post-period it increased to $2.62. However, Allegeny's average limit order book spread was $2.74 in both the pre-period and the post-period.

[11] Trading volume, unlike the spread and depth measures, is likely to have a upward trend which is unrelated to the tick size

reductions in both the quoted spread and quoted depth are largest for frequently traded stocks. In fact, the average quoted spread actually *increased* for the most infrequently traded stocks.

Due to the limitations in the data available to previous researchers, earlier research on the impact of a tick reduction has been limited to the information available in Table I. Consequently, inferences made from the results in Table I must be limited to noting that liquidity demanders trading sizes less than or equal to the reduced quoted depth have realized a transaction cost decrease. For liquidity demanders trading sizes larger than the reduced quoted depth, the improved bid and ask prices only apply to a portion of their required size. Absent additional liquidity provided by the floor, for the remainder of their trades, the sequence of prices and depths further into the limit order book also apply. For larger size orders, inferences about the transaction costs cannot be made without knowing how liquidity further into the limit order book has been altered by the tick reduction. Having the benefit of a richer data set, we simultaneously assess the effect of the reduction in the bid-ask spread and the effect of the change in depth – both at the quotes and throughout the limit order book – in order to assess the impact on overall liquidity.

Table II provides some results of how the limit order books have been altered as a result of the tick size reduction. One measure of how the limit order book has changed is the spread between the best limit price on the buy side and the best limit price on the sell side of the limit order book. As noted in Kavajecz (1998), this limit order book spread need not be equal to the spread quoted by the specialist.[12] In aggregate, the limit order book spread *increased* by \$0.03 or 9.1%, which is statistically significant at the 1% level. However, this increase is not uniform across quintiles. While the limit order book spread displays a statistically significant increase for the most infrequently traded stocks, it displays a statistically significant decrease for those stocks that are traded more frequently. Further evidence of the important difference across

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reduction. As a result, trading volume is not shown because no control sample is available to help assess whether the increase was abnormally high. While we do not specifically control for variance changes, Pruitt, Van Ness and Van Ness (1998) find that the variance was lower during the post-period. Since a lower variance would – if anything – predict an *increase* in limit order placement due to the option nature of limit orders, not specifically controlling for variance should bias our results *against* finding a reduction in liquidity.

quintiles is the fact that the quoted spread and the limit order book spread are the same for the most actively traded stocks both before and after the change ($0.15 and $0.11, respectively), although this is not true for less frequently traded stocks.

These results reveal that the impact of the tick reduction is not as clear-cut as the quoted spread results suggest. Like the quoted depth results reported in Table I, depth on the limit order book at the best limit order prices decreased significantly, with the largest decline occurring in the most frequently traded stocks. Despite the substantial reduction in the limit order depth at the best prices, we find that the *total* cumulative limit order book depth actually increased by an average of eight percent. Thus, determining where depth is positioned on the limit order book is paramount to assessing the impact of the tick size reduction. While stocks in the middle quintiles suffered a statistically significant decrease, both the high and low quintiles show statistically *insignificant* increases. If the tick size reduction incorporated a shift in the existing shares to prices further away from the quotes then even if overall new shares are added to the limit order book, liquidity may have been reduced for certain size orders.

The important measure, therefore, is how the cumulative depth has been affected. To illustrate this point, suppose that prior to the tick reduction a stock had a quoted price schedule of 20 bid, 20 1/8 ask with corresponding depths of 1,000 and 2,000 shares. (Assume that the specialist is choosing to add no additional depth beyond that provided by the limit order book.) Immediately after the tick size reduction, the quoted price schedule is revised to 20 bid, 20 1/16 ask with the depths being 500 shares at the bid and 800 shares at the ask. A liquidity demander who wishes to buy 800 or fewer shares is clearly better off under the smaller tick size, however, a liquidity demander who wishes to buy more than 800 shares could be better off or worse off depending on the cumulative depth on the limit order book. Without knowing the exact size that the larger liquidity demander wishes to trade, a sufficient condition for this large liquidity demander to be better off would be if the cumulative depth on the limit order book at each price level increased or at worst

[12]The specialist has the ability to supplement liquidity provided by the limit order book with floor interest as well as his own interest. The specialist can supplement liquidity by posting a better price than that on the limit order book or by adding depth to that

remained unchanged. If so, we could conclude that the transactions costs faced by this liquidity demander would have been reduced regardless of the amount he wishes to trade.

Table III displays the change in the cumulative depth on the limit order books for limit prices that are as far as fifty cents away from the opposite side quote.[13] By adding up all of the depth available on the limit order book, starting from the price quoted by the specialist on the opposite side (i.e., the ask for buy side depth, or the bid for sell side depth), we measure the cumulative depth that is available to a liquidity demander immediately. Measuring cumulative depth from the opposite side of the quote accounts for the changes in the quoted spread that occurred due to the change in tick size.

Evidence in Table III reveals that cumulative depth falls significantly for both sides of the market out as far as half a dollar away from the opposite side quote, with the strongest decline for frequently traded stocks. Depth has been reduced for prices both near and relatively far away from the quoted bid or ask. For example, the average cumulative depth for all 100 stocks an eighth away from the ask was 6,877 before the change, but only 5,973 afterwards. This decrease of 904 shares is significant at the 1% level. Depth further out on the limit order book showed similar significant declines. While the decline occurred in all trading volume quintiles, it was sharper in the more frequently traded stocks. For the more (less) frequently traded stocks, the average cumulative depth an eighth away from the ask was 18,031 (1,438) before the change but only 15,392 (1,281) afterwards, resulting in a statistically significant decrease of 2,639 (157) shares. Moreover, this change in depth was even more noticeable further out on the limit order book. Overall, the results of Table III indicate that no clear statement about liquidity can be made *ex ante* without empirically evaluating the transaction costs associated with different trade sizes before and after the tick size reduction.

Tables IV and V measure costs (from the midpoint of the bid-ask spread) facing a liquidity demander based on the number of shares that he wishes to transact. Table IV calculates these costs as if the trade were

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already on the limit order book.

executed solely against the limit order book, while Table V calculates the costs using both the depth in the limit order book plus any additional depth contributed by the floor that is displayed in the specialists' quotes. All figures are average share prices for that size transaction expressed as percentage distance from the quoted bid-ask spread midpoint. These tables are based on a shapshot in time and represent the cost to orders of different sizes submitted at that time that will be filled solely by the stated liquidity on the limit order book (Table IV) or limit order book and the stated liquidity from the floor (Table V). As such, it does not account for any additional non-displayed liquidity that is available from the floor, as noted by Sofianos and Werner (1997).

The advantage of this analysis is that it directly measures the net impact of the spread decline and the cumulative depth decline. The left side of Tables IV and V show the costs facing a trader wishing to sell shares, while the right side shows the costs facing a trader wishing to buy shares. As an example, suppose a trader wanted to sell 1,000 shares of a large (frequently traded) stock, assume that the quoted bid-ask midpoint proxies for the expected value of the stock. Then after the tick size reduction, the trader would receive twenty-two basis points less than the midpoint (assuming that the trade was executed solely against the limit order book) for the execution. If we include any additional depth included in the specialist's quote, then the trader would receive twelve basis points less. For a fifty dollar stock, these percentages amount to a loss in selling the shares of $0.11 per share and $0.06 per share, respectively. As such, the rows in Panels A and B represent the slope of the demand and supply curves in place for shares before and after the tick size reduction.

Panel C of Table IV indicates how these cost calculations have changed since the minimum tick size reduction using only the liquidity on the limit order book. Throughout Panel C, positive figures represent decreases in costs to liquidity demanders while negative signs represent increases in costs. In Table IV, we see that while the most frequently traded stocks have generally realized statistically significant improvements

[13] We also calculated the changes in cumulative depth measured from the same side quote. The results, not reported here, are substantively similar.

for smaller sizes, the result is by no means universal. Transaction costs for infrequently traded stocks have increased even for a minimum round lot trade.

Table V considers all the publicly stated liquidity, accounting for not only the limit order book but also the specialist and floor broker interest displayed by the specialist in his quotes. As Panel C of Table V indicates, the inclusion of this floor interest causes a sharp improvement in the cost change, particularly for smaller share sizes. In total, the tick size reduction has produced a statistically significant decrease in the costs for smaller trades, and a statistically significant increase in the costs for larger trades. [14]

Overall, these findings are consistent with the results in Jones and Lipson (1998), which shows a decrease in actual transaction costs for smaller sized trades but an increase for larger trades. Our analysis can help explain the results found by Jones and Lipson in that there is less cumulative depth that is immediately available on the limit order book. While this decrease would not affect smaller orders, it will affect larger ones. Combining our results on the limit order book with the transaction results of Jones and Lipson, we can infer that even if some of the liquidity providers moved their liquidity provision from the limit order book to the NYSE floor, overall liquidity has been decreased.

In total our results are consistent with previous empirical research in that we document a reduction in quoted spreads of 14.3%, and a reduction in quoted depth of 48.4%. In addition, we find that the cumulative depth on the book has declined and the volume on the limit order book has shifted way from the quotes. The combined effect of the quoted spread reductions and quoted and cumulative depth reductions is a transaction cost improvement for the most frequently traded stocks and a transaction cost deterioration for the most infrequently traded stocks, especially for the larger trade sizes.

[14]The notable difference in transaction costs between the buyside and sellside of the market is a product of how we defined our reference point, the quoted bid-ask spread midpoint. Over the time period considered in the study, the market as a whole was rising. During this period of rising prices, the quoted bid-ask spread tended to be positioned closer to the sellside of the limit order book than the buyside of the limit order book. Consequently, measurements of the deviations of average transaction prices from the bid-ask midpoint will likely favor buying shares from the sellside of the market over selling shares from the buyside of the market. With that in mind, caution should be exercised in interpreting these results as imparting an asymmetric effect on the sides of the market. For further discussion on the rationale for this quote setting behavior see Kavajecz (1998).

IV. The Effect on Liquidity Providers

While the previous section described the macro effects of the tick reduction, this section investigates on a micro level how the behavior of particular groups of liquidity providers has changed since the implementation of the minimum tick size reduction. While the impact of the change on any group is endogenous to the new equilibrium, it is useful to analyze some of the observed changes in specific aspects of their behavior.

A. Specialists and NYSE Floor Members

The results of the previous section demonstrate that liquidity provided by floor members through the specialists' quotes plays a key role in decreasing the costs that liquidity demanders face for virtually all trades sizes.[15] One way specialists (either for their own account or on behalf of a floor member) accomplish this is by quoting a price/quantity schedule that either improves upon the best prices on the limit order book or matches the best prices on the book and adds depth to the shares already on the book. As liquidity providers, floor members, like limit order traders, may be less willing to display liquidity given the reduction in the tick size. However, unlike limit order traders, the specialist is required to maintain a presence in the market given his special status in the market process. An important consequence of the minimum tick size reduction would be how much, if any, floor brokers and specialists have decreased their contribution to quoted depth.

Table VI breaks down the percentage of time floor members actually added depth to the displayed quote as well as the relative share contributions to displayed depth from both the specialist's quote and limit

[15]This is not to suggest that without a specialist or floor traders transaction costs would increase precipitously. The liquidity provided by the limit order book, floor traders and the specialist are jointly determined, with each provider conditioning on the presence of its competitor. Thus, absent a specialist and/or floor traders, limit orders would likely be more aggressive in providing liquidity since they no longer have to face the 'second adverse selection problem' discussed by Rock (1990) and Seppi (1997).

order book.[16] The first column on the buy and sell side represents the percentage of time that the specialist's quote provides additional liquidity – either by improving upon the limit order book price or by adding depth to that already provided by the book. The limit order depth represents the average depth, denominated in shares, provided by the limit order book, while the floor depth represents the average additional depth contributed to the displayed quote by the NYSE floor through the specialists' quotes. Table VI indicates that NYSE floor members are more (less) frequently adding to the displayed depth on the sellside (buyside) of the market since the tick reduction. This statistically significant result is consistent with the earlier finding that the cost improvement was substantially larger on the sellside of the market since the implementation of sixteenths. However, this result may also be a product of the rising market. When we average the buy and sell sides of the market, the percentage of time the specialist's quote does not add depth remains stable (51.7% before the tick size change; 52.0% after). Despite the relatively unchanged frequency of additional floor displayed depth, the level of displayed depth provided has fallen on average, especially for the most actively traded stocks. In particular, the floor's contribution to displayed depth has fallen by 54.8% on the buyside and 17.0% on the sellside.

Another way specialists play a role in decreasing costs is to stop incoming orders as in Ready (1996). Stopping an order is a way in which a specialist can guarantee an execution price to an order while holding it for the possibility of price improvement. As the tick size is reduced we might expect the volume of stopped orders to increase as the finer price grid may enable specialist to price improve orders more easily. The analysis of the order records in Table VII shows that the ratio of stopped order volume to market order volume increased by 15%.

Thus, we conclude that while the tick reduction has not altered the strategies of NYSE floor members with respect to the frequency of contributing depth to specialists' quotes, it has decreased the level of depth displayed and may have increased specialists' propensity to stop incoming orders for price improvement.

[16]Again, strictly speaking, the depth contribution attributed to the specialist is a combination of the specialist own interest and the interest expressed by the floor brokers in the crowd. The data do not allow us to partition this further.

B. Limit Order Traders

While we have discussed the aggregate effect on all limit order traders, it is useful to investigate the decision problems of individual limit order traders. When considering a liquidity provision strategy, each limit order trader weighs the profit to be gained if a particular order is executed against the loss incurred by that specific trader if that same order goes unexecuted. Work by Handa and Schwartz (1996) and Harris and Hasbrouck (1996) show that this tradeoff determines whether, and at what limit price, traders submit their limit orders. If we further assume that the market to supply liquidity is competitive as modeled by Rock (1990), Hollifield, Miller and Sandås (1996), Seppi (1997) and Sandås (1998), limit orders will be placed at a given limit price until the expected profit from supplying liquidity at that limit price is driven to zero. In this competitive environment, only inframarginal traders earn positive profits from providing liquidity. This assumption is a useful reference point to understand better the impact that reducing the minimum tick size had on individual limit order traders.

In this competitive limit order market, if the minimum tick size were a binding constraint for a given stock, a tick size reduction would allow those limit order traders wishing to provide liquidity at the new tighter spread a chance to do so. There may be limit order traders who do *not* wish to provide liquidity at the new tighter spread and who would therefore lose their priority over other orders because of the tick reduction. This reshuffling of the limit order queue may cause some limit order traders to reduce their contribution to depth and others to leave the market entirely.

A limit order trader operating in this reduced tick size environment has a number of ways to improve the profitability of providing liquidity. First, for any given level of depth provided, a limit order trader may find it more attractive to split their order and place the orders on multiple limit prices. This strategy would allow the trader to compete on price using only a fraction of his contributed depth. The limit order book data confirm this intuition. The fraction of shares on the limit order book that are part of 1,000 share or larger

orders increased by 5.3% while the fraction of shares that are part of orders less than or equal to 1,000 shares increased by 17.3%.

Second, because of the tick size reduction, the implicit subsidy furnished to liquidity providers was reduced. A trader wishing to recapture some of this subsidy may choose to place their limit orders slightly further from the quotes, a result we found earlier in looking at the change in the distribution of the cumulative depth. Conditional on a limit order trader placing his limit order further from the quote, he must be more patient in order to realize the profit associated with his less aggressive limit order. We might expect that patience would be revealed in the duration of an order or length of time an order is to remain active. As Table VII indicates, we find that the duration of limit orders increased statistically significantly as good-'til-cancelled orders increased their proportion of shares on the limit order books by an average of 1.5 percentage points.

Third, the increased price grid offers limit order traders more flexibility in choosing limit prices. That additional flexibility might manifest itself as an increase in the limit order cancellation rates, as limit order traders are better able to reposition their orders if necessary. The results in Table VII are consistent with this argument as the order flow data reveal a statistically significant increase of 6.2 percentage points in the ratio of cancelled limit orders to total limit orders submitted.

V. Asymmetric Information: Stocks vs. Closed-end Funds and Trusts

The ten Closed-End Funds and Trusts in the original data set provide a nice contrast to the other 100 stocks in our sample in that the characteristics and behavior of their limit order books are substantially different from that of the other stocks. Table VIII replicates the results for portions of Tables I to III for the 10 closed-end funds. By comparing the results in Table VIII with those from other tables, we are able to compare the differences between assets with relatively certain underlying values (closed-end funds and trusts) with assets whose underlying values are more uncertain (the rest of the sample). Surprisingly, the results for the two samples are quite different. Specifically, the number of shares on the limit order books range from

two to four times that of the average stock in the regular sample. In addition, depth at the quote is twice as large as the largest stocks in the regular sample.

The difference in the limit order books is due to the substantially smaller adverse selection problem that these stocks face, as argued in Neal and Wheatley (1998). To illustrate this point, compare the following two assets. The first asset has a fixed and known value that is common knowledge to all market participants, the second asset has an uncertain value from some known distribution with known moments. Consider the decision to provide liquidity for each of these two assets by submitting limit orders. In the case of the first asset, since all market participants know the true value of the asset, liquidity providers will be willing to provide an infinite amount of depth for anyone desiring liquidity. However, in the case of the second asset, depending on the variance of the distribution and degree of adverse selection risk, traders may or may not be willing to supply liquidity for this asset. When the traded asset is a closed-end fund or trust, the value of the underlying asset is reasonably well known, since net asset values are published weekly. For these types of assets, it is doubtful that other traders will have superior information. Consequently, the normal adverse selection problem faced by most market participants should be drastically reduced. As a result, for any given limit price away from the quotes, liquidity providers for closed-end funds and trusts are more willing to provide liquidity than if the asset was not a closed-end fund or trust. Moreover, given that the costs of entry into the market to supply liquidity are low, we would expect to see strong competition between those liquidity providers.[17]

Interestingly, due to the strong competition to provide liquidity, the behavior of the closed-ends funds and trusts most closely mirror the effect that proponents of minimum tick size reduction projected. Like the other stocks in our sample, the quoted spread and quoted depth decreased for the closed-end funds and trusts. However, unlike the other stocks, the cumulative depth for the closed-end funds and trusts *increased* as far

[17] Discussions with the specialists who trade these particular stocks revealed that very often liquidity providers, some of whom are exchange members, place large buy and sell limit orders equidistant from the respective posted quotes.

as fifty cents away from the opposite side quote. The result was a substantial decrease in the costs faced by liquidity demanders for order sizes under 10,000 shares in these funds and trusts.

The reason this result did not hold for all of the sample was that the stocks in the regular sample bear a much greater adverse selection cost. The combination of high adverse selection costs and a reduction in the minimum tick size creates an environment where liquidity providers chose to reduce their participation, potentially to zero. Our results that less frequently traded stocks, which are likely to have high adverse selection costs as per Easley, Kiefer, O'Hara and Paperman (1996), display the least improvement from the tick size change is consistent with this argument.

V. Conclusion

Our results demonstrate that the most frequently traded stocks saw an improvement in the costs they faced while infrequently traded stocks saw a deterioration in the costs for larger order sizes. Consequently, moves by equity markets to decrease their minimum tick sizes are not an unambiguous welfare enhancement for liquidity demanders.

Since an exchange is set up to provide liquidity, modifications to the market structure that enhance the liquidity provision capacity serve to make the exchange a more viable entity. As such, our analysis highlights two important points when considering rule changes such as changing the minimum tick size. First, merely examining changes in the quoted spread and quoted depth is insufficient to assess changes in overall market liquidity. The level and position of depth on the limit order book is crucial to understanding how liquidity has been altered. Second, markets and regulators must consider the ramifications and incentives of their actions on liquidity providers as well as liquidity demanders.

While many might argue that the structure of the trading mechanism should be set up to benefit small investors, how best to benefit these retail traders is not as simple as minimizing the quoted spread. Ultimately, while small investors in their trading portfolio may only transact a few round lots at a time, these same small investors may do the bulk of their investing through mutual funds. To the extent that costs of

transacting have increased for fund managers, that added cost will likely get passed on the small investors who use the fund as an investment vehicle.

Should exchanges decide to continue moving toward smaller minimum tick sizes, our results suggest that a tiered tick function based upon a stock's trading activity may be preferable to a uniform reduction. Frequently traded stocks would have the smallest minimum tick size, while infrequently traded stocks would have a coarser price grid to promote liquidity provision. This policy would allow frequently traded stocks to realize further reductions in transaction costs through increased liquidity provider competition while maintaining incentives to provide liquidity for infrequently traded stocks.

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Table I
Quoted Spreads and Quoted Depth

This table provides data on the spreads and their associated depths quoted by the specialist for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. The stocks are then separated into quintiles based on their December 1996 average daily trading volume. The spreads and depth are equally-weighted averages of thirty minute snapshots in time. Depth numbers are the average of bid and ask depth. Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category are rejected at the 1% level.

	Quoted Dollar Spread	Quoted Percentage Spread	Average Quoted Depth
Panel A: Pre-Reduction Period			
All 100 Stocks	0.21	0.86	9,353
By Volume			
High	0.15	0.42	24,324
2	0.17	0.47	8,823
3	0.17	0.92	7,350
4	0.18	1.17	3,844
Low	0.37	1.33	2,424
Panel B: Post-Reduction Period			
All 100 Stocks	0.18	0.69	4,824
By Volume			
High	0.11	0.28	10,467
2	0.13	0.32	5,059
3	0.13	0.63	4,000
4	0.14	0.85	2,793
Low	0.41	1.38	1,802
Panel C: Change from Pre- to Post-Reduction Period			
All 100 Stocks	**-0.03**	**-0.17**	**-4,529**
By Volume			
High	**-0.04**	**-0.14**	**-13,857**
2	**-0.04**	**-0.15**	**-3,764**
3	**-0.04**	**-0.29**	**-3,350**
4	**-0.04**	**-0.32**	**-1,051**
Low	**0.04**	0.05	**-622**

Table II
Limit Order Book Characteristics

This table provides data on characteristics from the limit order books for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). The stocks are separated into quintiles based on their December 1996 average daily trading volume. Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Average Number of Orders is the average number of limit orders on the limit order book. Average Order Size is the average size in shares of the limit orders on the limit order book. Total Cumulative LOB Depth is the average total cumulative depth of the limit order book. Best LOB Quote Depth is the depth at the best buy or sell limit order prices on the limit order book. Limit order book spread is the spread between the best buy or sell limit order prices on the limit order book. Depth numbers are the average of bid and ask depth. Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category are rejected at the 1% level.

	Average Number of Orders	Average Order Size	Total Cumulative LOB Depth	Best LOB Quote Depth	LOB Dollar Spread	LOB Percentage Spread
Panel A: Pre-Reduction Period						
All 100 Stocks	105	1,358	114,588	9,111	0.33	1.25
By Volume						
High	381	1,300	402,967	22,312	0.15	0.42
2	55	1,139	54,447	8,009	0.18	0.50
3	46	1,919	61,419	7,634	0.22	1.06
4	31	1,149	34,998	4,350	0.26	1.39
Low	14	1,284	19,155	3,255	0.85	3.01
Panel B: Post Reduction Period						
All 100 Stocks	127	1,234	124,049	4,667	0.36	1.40
By Volume						
High	487	1,196	457,507	9,801	0.11	0.31
2	57	1,008	52,198	4,254	0.15	0.38
3	45	1,642	57,637	3,816	0.22	1.10
4	30	1,097	32,817	3,024	0.31	1.42
Low	14	1,225	20,062	2,440	1.07	4.02
Panel C: Change from Pre- to Post-Reduction Period						
All 100 Stocks	22	**-124**	**9,461**	**-4,444**	**0.03**	**0.15**
By Volume						
High	**106**	**-104**	54,540	**-12,511**	**-0.04**	**-0.11**
2	**2**	**-131**	**-2,249**	**-3,755**	**-0.03**	**-0.12**
3	1	**-277**	**-3,782**	**-3,818**	0.00	0.04
4	**-1**	**-52**	**-2,181**	**-1,326**	**0.05**	0.03
Low	0	**-59**	907	**-815**	**0.22**	1.01

Table III

Cumulative Depth Distribution on the Limit Order Book

This table provides data on the cumulative depth on limit order books for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). The stocks are separated into quintiles based on their December 1996 average daily trading volume. Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Cumulative Depth is the average cumulative depth of the limit order book as measured from the quote posted by the specialist on the opposite side (the ask for the buyside depth; the bid for the sellside depth). Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category are rejected at the 1% level.

	Buyside				Sellside			
	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2
Panel A: Pre-Reduction Period								
All 100 Stocks	6,877	14,706	20,427	24,454	8,155	17,504	24,640	30,184
By Volume								
High	18,031	37,078	51,145	61,434	22,283	46,680	65,541	80,914
2	5,984	13,122	17,546	20,169	7,008	15,125	19,931	23,141
3	5,704	11,707	15,890	19,277	6,126	12,695	19,136	24,530
4	3,092	6,790	9,537	11,691	2,811	6,761	9,751	12,008
Low	1,438	4,580	7,698	9,322	2,251	5,663	7,999	9,271
Panel B: Post-Reduction Period								
All 100 Stocks	5,973	11,897	16,191	19,732	4,530	11,755	17,295	21,712
By Volume								
High	15,392	29,723	40,838	49,812	11,754	30,488	45,185	57,240
2	5,659	11,351	14,607	16,967	4,050	10,219	14,300	17,110
3	4,197	8,318	11,227	13,719	3,232	8,259	11,871	14,799
4	3,065	6,248	8,534	10,381	2,106	5,452	7,965	9,946
Low	1,281	3,345	5,095	7,032	1,385	4,043	6,718	8,916
Panel C: Change from Pre- to Post-Reduction Period								
All 100 Stocks	**-904**	**-2,809**	**-4,236**	**-4,722**	**-3,625**	**-5,749**	**-7,345**	**-8,472**
By Volume								
High	**-2,639**	**-7,355**	**-10,307**	**-11,622**	**-10,529**	**-16,192**	**-20,356**	**-23,674**
2	-325	**-1,771**	**-2,939**	**-3,202**	**-2,958**	**-4,906**	**-5,631**	**-6,031**
3	**-1,507**	**-3,389**	**-4,663**	**-5,558**	**-2,894**	**-4,436**	**-7,265**	**-9,731**
4	-27	**-542**	**-1,003**	**-1,310**	**-705**	**-1,309**	**-1,786**	**-2,062**
Low	**-157**	**-1,235**	**-2,603**	**-2,290**	**-866**	**-1,620**	**-1,281**	-355

Table IV
Demand and Supply Schedules
Limit Order Book Only

This table provides data on the demand and supply schedules derived from limit order books for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). The stocks are separated into quintiles based on their December 1996 average daily trading volume. Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Values are measured as the average percentage markup over the bid-ask spread midpoint using only the depth provided by limit orders on the book. Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category are rejected at the 1% level. NA is used when less than 80% of the stocks in that category had sufficient depth to generate meaningful numbers.

	LOB Buy Side						LOB Sell Side					
	10,000 shs	5,000 shs	2,500 shs	1,000 shs	500 shs	100 shs	100 shs	500 shs	1,000 shs	2,500 shs	5,000 shs	10,000 shs
Panel A: Pre-Reduction Period												
All 100 Stocks	-2.23	-1.96	-1.38	-0.94	-0.78	-0.64	0.62	0.70	0.78	0.99	1.13	1.51
By Volume												
High	-0.55	-0.41	-0.31	-0.25	-0.24	-0.22	0.19	0.20	0.21	0.24	0.29	0.39
2	-1.22	-0.81	-0.53	-0.35	-0.30	-0.26	0.24	0.26	0.29	0.37	0.49	0.74
3	-3.18	-1.75	-1.09	-0.72	-0.62	-0.52	0.56	0.58	0.62	0.81	1.15	1.68
4	-2.64	-1.95	-1.47	-0.98	-0.82	-0.72	0.69	0.78	0.92	1.30	1.74	2.75
Low	NA	-5.49	-3.80	-2.49	-1.97	-1.49	1.47	1.78	2.04	2.74	NA	NA
Panel B: Post-Reduction Period												
All 100 Stocks	-2.86	-2.46	-1.72	-1.15	-1.02	-0.79	0.61	0.66	0.68	0.92	1.13	1.53
By Volume												
High	-0.67	-0.42	-0.30	-0.22	-0.19	-0.17	0.14	0.15	0.17	0.22	0.31	0.50
2	-1.56	-1.04	-0.59	-0.35	-0.26	-0.21	0.18	0.22	0.26	0.40	0.59	0.98
3	-3.12	-1.90	-1.20	-0.87	-0.78	-0.63	0.45	0.53	0.62	0.86	1.17	1.72
4	-3.11	-2.87	-1.99	-1.33	-1.04	-0.80	0.62	0.72	0.83	1.20	1.79	2.80
Low	NA	-7.15	-5.00	-3.13	-2.97	-2.24	1.75	1.87	NA	2.42	NA	NA
Panel C: Changes from Pre- to Post-Reduction Period												
All 100 Stocks	**-0.63**	**-0.50**	**-0.34**	**-0.21**	**-0.24**	**-0.15**	0.01	**0.04**	**0.10**	**0.07**	0.00	0.02
By Volume												
High	**-0.12**	-0.01	0.01	**0.03**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.02**	**-0.03**	**-0.11**
2	-0.34	**-0.23**	**-0.06**	0.00	**0.04**	**0.05**	**0.06**	**0.04**	**0.03**	-0.03	**-0.10**	**-0.24**
3	-0.06	-0.15	-0.11	**-0.15**	**-0.16**	**-0.11**	**0.11**	**0.05**	0.00	-0.05	-0.02	-0.04
4	-0.67	**-0.92**	**-0.52**	**-0.35**	**-0.22**	**-0.08**	**0.07**	**0.06**	**0.09**	**0.10**	0.05	0.05
Low	NA	**-1.66**	**-1.20**	**-0.64**	**-1.00**	**-0.75**	**-0.28**	-0.09	NA	**0.24**	NA	NA

Table V
Demand and Supply Schedules
Limit Order Book and Specialists' Quotes

This table provides data on the demand and supply schedules derived from limit order books for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). The stocks are separated into quintiles based on their December 1996 average daily trading volume. Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Values are measured as the average percentage markup over the bid-ask spread midpoint using depth provided both by the specialist's quotes as well as that in the limit order book. Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category (with all five quintiles available) are rejected at the 1% level (except for the 100 share category on both sides). NA is used when less than 80% of the stocks in that category had sufficient depth to generate meaningful numbers.

	LOB Buy Side						LOB Sell Side					
	10,000 shs	5,000 shs	2,500 shs	1,000 shs	500 shs	100 shs	100 shs	500 shs	1,000 shs	2,500 shs	5,000 shs	10,000 shs
Panel A: Pre-Reduction Period												
All 100 Stocks	-2.01	-1.58	-0.98	-0.58	-0.46	-0.37	0.37	0.45	0.53	0.81	0.94	1.32
By Volume												
High	-0.39	-0.26	-0.21	-0.19	-0.18	-0.18	0.17	0.17	0.18	0.20	0.23	0.31
2	-0.96	-0.58	-0.34	-0.22	-0.20	-0.19	0.18	0.19	0.21	0.27	0.38	0.59
3	-2.63	-1.33	-0.78	-0.49	-0.42	-0.40	0.39	0.40	0.44	0.60	0.89	1.40
4	-2.41	-1.67	-1.15	-0.68	-0.55	-0.50	0.49	0.51	0.60	0.92	1.39	2.36
Low	NA	-4.55	-2.62	-1.36	-0.98	-0.57	0.60	1.00	1.32	2.53	2.54	NA
Panel B: Post-Reduction Period												
All 100 Stocks	-2.64	-2.02	-1.24	-0.62	-0.39	-0.26	0.26	0.36	0.45	0.68	0.92	1.32
By Volume												
High	-0.50	-0.27	-0.17	-0.12	-0.11	-0.11	0.10	0.11	0.11	0.15	0.23	0.39
2	-1.32	-0.70	-0.35	-0.17	-0.13	-0.12	0.11	0.13	0.16	0.27	0.44	0.81
3	-2.72	-1.49	-0.79	-0.45	-0.31	-0.24	0.25	0.28	0.35	0.56	0.87	1.41
4	-2.89	-2.29	-1.43	-0.66	-0.42	-0.34	0.34	0.38	0.50	0.87	1.40	2.43
Low	NA	-6.27	-3.43	-1.77	-1.02	-0.53	0.49	0.98	1.31	1.95	2.32	NA
Panel C: Changes from Pre- to Post-Reduction Period												
All 100 Stocks	**-0.63**	**-0.44**	**-0.26**	**-0.04**	**0.07**	**0.11**	**0.11**	**0.09**	**0.08**	**0.13**	0.02	0.00
By Volume												
High	**-0.11**	-0.01	**0.04**	**0.07**	**0.07**	**0.07**	**0.07**	**0.06**	**0.07**	**0.05**	0.00	**-0.08**
2	-0.36	**-0.12**	-0.01	**0.05**	**0.07**	**0.07**	**0.07**	**0.06**	**0.05**	0.00	**-0.06**	-0.22
3	-0.09	**-0.16**	-0.01	**0.04**	**0.11**	**0.16**	**0.14**	**0.12**	**0.09**	**0.04**	0.02	-0.01
4	-0.48	**-0.62**	**-0.28**	0.02	**0.13**	**0.16**	**0.15**	**0.13**	**0.10**	0.04	-0.01	**-0.07**
Low	NA	**-1.72**	**-0.81**	**-0.41**	-0.04	**0.04**	**0.11**	0.02	0.01	**0.58**	**0.22**	NA

Table VI

NYSE Floor Contribution to Displayed Quote Depth

This table provides data on the average floor contribution to the displayed quote depth for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). The stocks are separated into quintiles based on their December 1996 average daily trading volume. Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Depth from the Floor indicates the percentage of the time that the quotes have additional depth over that provided by the limit order book. LOB Depth is the depth at the quote that was from the limit order book; Floor Depth is the depth at the quote that was from floor participants. Differences in **bold** in Panel C are significant at the 1% level for both parametric and non-parametric tests. In Panel C, F-tests for equality across quintiles for each category are rejected at the 1% level.

	Buyside			Sellside		
	Depth From Floor (%)	LOB Depth	Floor Depth	Depth From Floor (%)	LOB Depth	Floor Depth
Panel A: Pre-Reduction Period						
All 100 Stocks	48.33	7,786	2,478	48.20	9,020	2,767
By Volume						
High	51.16	19,214	6,969	50.57	23,617	7,586
2	51.47	7,018	2,468	48.27	7,987	2,485
3	47.98	6,535	1,577	50.97	6,887	2,374
4	44.66	3,979	799	46.24	3,724	1,023
Low	46.39	2,187	580	44.92	2,889	367
Panel B: Post-Reduction Period						
All 100 Stocks	38.21	3,729	1,120	57.71	2,978	2,296
By Volume						
High	32.31	8,161	2,205	58.62	6,665	5,231
2	35.02	3,618	1,287	58.24	2,591	2,436
3	36.43	3,063	1,035	61.61	2,214	2,032
4	35.03	2,443	618	56.08	1,852	1,216
Low	52.28	1,363	458	54.01	1,567	563
Panel C: Change from Pre- to Post-Reduction Period						
All 100 Stocks	**-10.12**	**-4057**	**-1358**	**9.52**	**-6043**	**-471**
By Volume						
High	**-18.85**	**-11,053**	**-4,763**	**8.05**	**-16,950**	**-2,354**
2	**-16.45**	**-3,400**	**-1,181**	**9.97**	**-5,397**	-49
3	**-11.55**	**-3,472**	**-542**	**10.63**	**-4,672**	**-342**
4	**-9.63**	**-1,535**	**-181**	**9.84**	**-1,871**	**193**
Low	**5.89**	**-824**	**-121**	**9.09**	**-1,322**	**196**

Table VII
Effects on Particular Market Participants

This table provides data on selected results for particular market participants for the 100 NYSE stocks in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Stopped Orders (%) is the ratio of stopped order volume to market order volume. Orders greater than (less than or equal to) 1,000 shares is the fraction of shares on the limit order book that are part of orders whose total size is greater than (less than or equal to) 1,000 shares. Good-'til-cancel (%) is the percentage of shares on the limit order book that are good-'til-cancelled orders. Cancelled limit orders (%) is the percentage of cancelled limit orders to total limit orders submitted. Differences in **bold** are significant at the 1% level for both parametric and non-parametric tests.

	Pre-Reduction	Post-Reduction	Change
Panel A: Specialists			
Stopped Orders (%)	1.45	1.67	0.22
Panel B: Limit Order Traders			
Limit Orders Less than or Equal to 1,000 Shares	28,538	33,468	4,930
Limit Orders Greater than 1,000 Shares	86,051	90,582	4,531
Good-'til-Cancel (%)	66.1	67.6	**1.5**
Cancelled Limit Orders (%)	35.4	37.6	**2.2**

Table VIII
Closed-end Funds and Trusts

This table provides data for the 10 NYSE closed-end funds and trusts in our sample. The pre-reduction period includes data from May 27 to June 20, 1997. The post-reduction period includes data from June 30 to July 25, 1997 and from August 25 to September 19, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1998). Results are from equally-weighted averages of snapshots of the limit order book every thirty minutes. Panel A reports the results for closed-end funds and trusts for comparison to Table I; Panel B for Table II; and Panel C for Table III. Differences in **bold** are significant at the 1% level for both parametric and non-parametric tests.

	Pre-Reduction	Post-Reduction	Change
Panel A: Quoted Bid Ask Spreads and Volume (Table I)			
Dollar Spread	0.16	0.12	**-0.04**
Percent Spread	1.27	0.84	**-0.43**
Depth	42,612	25,055	**-17,557**
Panel B: Limit Order Book Characteristics (Table II)			
Total Cumulative LOB Depth	289,553	382,271	**92,718**
Best LOB Quote Depth	50,910	30,626	**-20,284**
Limit Order Book Spread ($)	0.21	0.16	**-0.05**
Limit Order Book Spread (%)	1.44	0.92	**-0.52**
Panel C: Cumulative Depth Distribution on the Limit Order Book (Table III)			
Buyside Only:			
1/8	49,732	70,796	**21,064**
¼	147,879	173,037	25,158
3/8	243,784	253,388	9,604
½	314,642	328,422	13,780