Stock Splits, Liquidity and Limit Orders

By

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Abstract

We use non-public NYSE system data to study the effect of stock splits on liquidity by documenting changes in the limit order book, execution costs, and trading activity. We find that depth available in the limit order book at various dollar distances from the mid-quote increases after a stock split, but the depth available at various percentage (split-adjusted) distances declines substantially. In general, we observe a slight increase in the use of limit orders rather than market orders, and fill rates are largely unchanged. Consistent with these results, the realized execution cost (in percent) of limit orders declines dramatically while the realized execution cost for market orders increases. Overall, despite a 10 basis point increase in the proportional effective half-spread, we find little evidence of a change in execution costs across all orders. Finally, while trading activity generally declines following stock splits, we observe a substantial increase in the number of submitted orders, an increase in the proportion of trading volume that originates from individuals, and an increase in market buys by individuals.

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1. Introduction

The motivation behind stock splits is a puzzle that continues to hold the interest of academics and practitioners alike. While ample evidence suggests that stock splits return prices to a "normal" trading range, the factors that determine this optimal trading range are not clearly understood.[1] In fact, despite a positive market reaction to stock split announcements, market quality actually appears to decline after a split, with sharp increases in spreads and volatility.[2] This paper examines the effects of stock splits on several measures of market quality not previously studied. In particular, we examine changes in the limit order book, the execution costs of limit orders and market orders, and trading activity. Our results provide a more complete picture of the changes in market quality than what is provided by studies of trades and quotes alone.

Limit orders compete with market makers for order flow and also provide a pool of trading interest (the limit order book) that can absorb temporary order flow imbalances. For this reason, changes in limit order activity, both in terms of quantity and placement, may be closely related to changes in market quality.[3] Furthermore, while a binding minimum tick size is likely to widen spreads and alter depth close to the mid-quote, it is unclear how depth further away

[1] See, for example, Lakonishok and Lev (1987) and Angel (1997)

[2] Merton (1987), Lamoureux and Poon (1987), Brennan and Hughes (1991), Maloney and Mulherin (1992), and Ohlson and Penman (1985), among others, examine changes in market quality around stock splits. Koski (1998) examines potential microstructure explanations for changes in volatility around stock splits.

[3] McInish and Wood (1995), Harris and Hasbrouck (1996), Greene (1995) and Seppi (1997) discuss the relation between limit orders and market quality. The choice between limit and market orders is explored theoretically in Cohen, Maier, Schwartz and Whitcomb (1981) and Holden and Chakravarty (1995), while empirical evidence on the costs and pricing strategies of limit orders is provided in Biais, Hillion, and Spatt (1995) and Griffiths, Smith, Turnbull and White (1999).

from the quote will be affected. A unique contribution of this paper is to document changes in the limit order book, limit order volume, and limit order placements around stock splits.

Another contribution of this study is to examine execution costs for both market *and* limit orders around stock splits. Since public market orders often trade against public limit orders, an increased cost to one trader may be a savings to another. Thus, even though spreads increase following stock splits, the overall effect on execution costs is not clear. This is particularly true on the NYSE where specialists participate in only a small fraction of trades (see Sofianos and Werner (1997)).

Our analysis uses non-public system order data provided by the NYSE. These data allow us to distinguish between market and limit orders, to track cancellations and executions, and to identify orders originating directly from individuals. These data are also sufficient to recreate the limit order book following Kavajecz (1999), and measure trading costs as in Harris and Hasbrouck (1996). Our analysis examines 2-for1 or greater stock splits in NYSE listed companies during the years 1995 and 1996.

We find that the total depth available in the limit order book declines on the bid side but is little changed on the ask side. On the other hand, the distance from the mid-quote to the best price in the limit order book (limit-book spread) and to the prices at which total depth of 5,000 and 10,000 shares would be available in the limit order book (5,000 and 10,000 share spreads) are closer to the prevailing mid-quote in dollar terms. Similarly, there is an increase in the total depth available in the limit order book (cumulative depth) at various dollar distances from the prevailing mid-quote. To understand how these changes will impact liquidity, however, we need to examine proportional distances rather than dollar distances. This is particularly true if we are

interested in potential effects on execution costs and volatility since these are measured proportionally.[4]

The limit-book spread and 5,000 and 10,000 share spreads are substantially larger as a proportion of the mid-quote following a stock split. For example, the 5,000 share spread increases on average from 1.57% to 2.17% on the bid side and from 1.03% to 1.99% on the ask side after a stock split. Similarly, at various proportionally identical (split-adjusted) distances from the prevailing mid-quote, the total number of shares available in the limit order book declines sharply. For example, cumulative depth up to $1/8 (split-adjusted) declines by about 2,600 shares on the bid side and by about 3,500 shares on the ask side following a split. These changes represent declines of over 30% from pre-split levels. We show that changes in the placement of limit orders, rather than changes in limit order executions, drive these changes. For example, we find that limit orders are placed, on average, 33 basis points away from the prevailing mid-quote before the split and 60 basis points after, while there is no significant change in execution rates. These results suggest a partial explanation for the changes in spreads and volatility commonly observed after stock splits may be changes in the limit order book.

We find that the execution cost for executed limit orders declines after a split while the cost for market orders increases. If we look at all executed orders, the mean change in the weighted average execution cost is indistinguishable from zero, while the median change is a decrease of 5 basis points. If we include a conservatively high penalty for non-execution of a limit order, the mean change in the weighted average execution costs across all orders is still

[4] Interpreting the results on dollar cutoffs is also difficult since there are two confounding effects. Traders may optimally employ dollar (tick) based trading strategies, in which case the increased depth at dollar distances suggests a greater willingness to place limit orders. On the other hand, if trading interests are based on proportional execution costs, then the increased depth at fixed dollar distances (proportionally greater distances) may simply reflect a movement along a demand schedule. We discuss interpretations of dollar distance results in the conclusion, paying particular attention to how our results relate to the ongoing debate on the effects of tick size on trading behavior.

indistinguishable from zero, though in this case the median change is an increase of about 5 basis points.[5] These results paint a very different picture of trading costs than what is seen in spreads. For example, the proportional effective half-spread (the average difference between the execution price and the mid-quote at the time of execution) increases by 10 basis points. Our results suggest, therefore, that the increase in trading costs associated with stock splits may not be as great as generally thought.

Finally, though we observe a decline in executed daily share volume after a stock split, we find a substantial increase in the number of orders (decrease in average order size), an increase in the proportion of order flow originating from individuals, and an increase in the number and volume of buys by individuals. These results provide direct evidence that stock splits are associated with an increase in trading activity by individuals.[6]

The rest of this paper is organized as follows. Section 2 discusses the sample and presents summary statistics. Section 3 presents the analysis of the limit order book, section 4 discusses limit order placements, and section 5 discusses execution costs. Section 6 discusses our results in light of a number of stock split debates.

2. Sample and Summary Statistics

The sample includes all 2-for-one or greater stock splits by NYSE firms listed in the Center for Research in Security Prices (CRSP) data set during 1995-1996. For each stock split, we obtain intraday Trade and Quote (TAQ) data and NYSE system (superDOT) order data for the period starting 60 days prior to the stock split and ending sixty days after the stock split. To

[5] The costs associated with unfilled orders (implementation shortfall) were described in Perold (1988) and are discussed in Harris and Hasbrouck (1996) and Griffiths, Smith, Turnbull and White (1999), among others.
[6] Studies of clientele effects include Merton (1987), Lamoureux and Poon (1987), Brennan and Hughes (1991), Maloney and Mulherin (1992), and Schultz (1998).

ensure valid estimates of the measures we examine, a split is included only if there are at least five days with system trades in the pre-split and post-split sample periods.

The number of splits, average split sizes, and firm characteristics are described in Table 1. This table lists 2-for-one and greater than 2-for-one stock splits separately. The sample of firms with 2-for-one stock splits is comparable to the sample of greater than 2-for-one stock splits with the exception of stock price. Not surprisingly, the stock price prior to the split is substantially greater for the larger splits. Given the small number of larger stock splits, we do not study these samples separately in the remainder of the paper. The mean pre-split stock price in our sample is $68.50, which is about twice the average stock price on the NYSE. These results are consistent with observations that stock splits return prices to "normal" trading ranges. For this reason, we follow Schultz (1998) and present all share and stock price values on a post-split basis throughout the paper.

2.1 Market Quality and Trading Activity

Summary statistics on market quality and trading activity are presented in Table 2. Here and throughout the paper, statistical tests compare the pre and post-split time periods by examining the distribution across firms of the change in mean values using a *t*-test or Wilcoxon signed rank test. Specifically, for each firm we calculate the mean daily values in the pre- and post-split sample periods separately. We then examine the distribution of the firm-by-firm changes in the mean values. Thus, we assume independence across firms and across the pre-split and post-split time periods. In general, statistical results for median changes are qualitatively identical to those for means.[7] In Table 2 we report both means and medians, though in the

[7] We also examined the distribution of pair-wise changes in medians, compared the distribution of pre-split and post-split event-time means and medians, and compared the distribution of pre-split and post-split daily firm values. Statistical inferences are similar using these alternative methods.

remainder of the paper we mostly report means in the tables and discuss any differences between mean and median results in the text.

Panel A of Table 2 shows market quality measures. We begin with an analysis of quoted and effective half-spreads. The quoted half-spread is equal to one half the difference between the ask and bid prices, while the effective half-spread is equal to the difference between the execution price of an executed trade and the mid-quote at the time of execution. We present half-spreads to be consistent with our analysis in sections 3 and 5. As in Conroy, Harris and Benet (1990), we find that *dollar* quoted half-spreads and effective half-spreads decrease while *proportional* quoted and effective half-spreads (dollar spread divided by mid-quote) increase.

To examine changes in volatility, we look at two volatility measures: the standard deviation of daily (close to close) returns and the average of the squared daytime excess returns (open-to-close return less the mean open-to-close return during the pre or post-split time periods, as appropriate). We use mid-quotes for these measures in order to eliminate transient effects from bid-ask error. Consistent with Koski (1998), we find evidence of an increase in volatility. We observe a significant increase in the mean volatility using the first measure, and the median volatility using both measures.

Trading activity measures are calculated from daily totals for each trading day in the sample. Panel B shows total NYSE trading activity (obtained from TAQ data) and NYSE trading activity as a percent of all activity.[8] NYSE market share is not 100% because of competition for order flow from regional exchanges and the Nasdaq. The NYSE is, of course, the dominant market for NYSE-listed firms.

[8] Schwartz (1991) and Hasbrouck, Sofianos and Sosebee (1993) provide a description of the NYSE trading procedures and features.

We find that daily share volume decreases by about 9% following a stock split. This result is consistent with Copeland (1979), Lamoureux and Poon (1987) though it differs from Desai, Nimalendran and Venkataraman (1998), who find no significant change. We find no evidence, however, of a change in total daily *dollar* trading volume as a result of the stock split. The change in market share is an interesting result. While there are no statistically reliable changes in mean market share based on dollar volume, we find evidence of decreases in median market share based on volume and decreases in both means and medians in market share based on the number of trades.[9]

Panel C of Table 2 summarizes the trading activity for system orders. For system trades, we observe a decline in trading activity, with significant declines in both buys and sells based on either dollar or share volume. Once again, we observe a significant increase in the number of orders. Note that for system orders, we observe whether orders are buys or sells and reliable distinctions can be drawn between these order types.

To compare system activity to total activity, one should compare the reported system numbers to twice the totals. This is necessary since the orders are one side of a trade whereas execution prints (as captured in trade data) are matched buys and sells. Thus, system orders account for roughly half of NYSE share volume during our sample period. We also observe a decrease in the proportion of trading volume executed through superDOT: from 52% to 45% for buys and from 49% to 45% for sells.

It should be emphasized that we can only analyze the electronic orders and cannot comment on whether there may be offsetting changes in floor orders. This applies both to the limit order book and execution costs. However, the changes we document here provide a

[9] The change in market share may be related to the increasing number of trades for the following reason. The vast majority of volume executed outside the NYSE is from smaller orders, and an increase in the number of orders with

detailed picture of changes in one important source of market activity. The limit order book, in particular, is an important source of liquidity to supplement what is available from the specialist and trading floor. Finally, since traders can choose between electronic and floor execution, competition between these modes of execution is likely to mean that changes in one will be paralleled by changes in the other.

2.2 Types of System Orders and Individual Trading Activity

In this section we present some summary statistics on the distribution of order flow across order types as well as the trading activity of individuals. The data we use provides information that allows us to identify orders that originated directly from individuals and therefore assess changes in individual trading activity without being forced to use trade size as a proxy for trader identity. It should be noted that not all orders are executed, so total *order* flow will generally exceed the amount of *executed* orders (trades) shown in Table 2, Panel C. Also, except where otherwise indicated, in the remainder of the paper we present results on share volume and not dollar volume (results are essentially identical in either case).

Table 3 provides information on the types and sources of system orders. In this table we also partition both on type of order (market orders, marketable limit orders, and limit orders) and whether orders originated directly from individuals (as opposed to institutions or exchange member firms). Marketable limit orders are limit orders in which the limit price is equal to or exceeds the opposite side quote (ask for a buy, bid for a sell) at the time the order enters the superDOT system.

While marketable limit orders execute essentially like market orders, they deserve particular attention for the following reason. Some traders may submit marketable limit orders

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little change in aggregate volume suggests an increase in small orders.

in order to limit the price variability of their execution. On the other hand, some traders may submit limit orders which, due to changes in market conditions from the time the order is placed to the time it reaches the NYSE, become marketable limit orders. Furthermore, marketable limits are intermediary between market orders and limit orders in their desire for immediacy of execution (see Griffiths, Smith, Turnbull and White (1999)).

Table 3 presents the daily total order flow for each order type and for individuals within each order type. We also analyze (1) the proportion of each order type relative to all orders, (2) the proportion of each order type originating from individuals, and (3) the proportion of all individual orders which are of a given order type. We test for changes in the daily proportions as well as changes in aggregate orders since we observe significant declines in trading volume in all classifications. In other words, we test for changes in the *distribution* of order flow as well as total order flow.

Consider the changes for each order type. Two things are important to notice. First, market orders account for only about 20% of orders while limit orders account for about 60% of orders. Marketable limit orders, of course, account for the rest. Even if we acknowledge that only about 40% of limit orders are executed, market orders are no more than about a third of all executed orders. It is the relative small proportion of market orders that makes it so important to consider all order types when evaluating execution costs. Only market orders are likely to execute at posted spreads, so studies of trade and quote data essentially capture the change in costs only for about 20% of orders (30% of executions). Second, while overall trading declines, we observe a statistically significant increase in the proportion of orders that are limit orders. Of course, the change in proportions is only about 1% for both buys and sells.

As for the trading activity of individuals, we observe a significant reduction in order flow for market sell orders but significant increases in both market buys and marketable limit order buys. Overall, there is a significant increase in buys by individuals after a split. More importantly, there are significant increases in the *proportion* of order flow originating from individuals for market buys and sells, marketable limit buys, and limit buys. For example, before a stock split, individuals generated about 23% of system market buy orders while after the stock split this rises to about 28%. In fact, though individuals account for very few limit orders (roughly 7% of the total), even here there is a significant increase. These results provide direct evidence that stock splits attract order flow from individuals and that individuals are more actively buying after a split.[10]

Table 3 also reports the percentage of limit orders that are do not expire automatically at the end of the day (specifically, orders that are 'good-until-cancelled' or 'good-until-executed'). These types of orders increase in absolute magnitude and as a percentage of limit orders. More importantly, since these orders are a small fraction of all orders, it is unlikely that our analysis of the limit order will be driven by old orders.[11] Interestingly, in Table 3 we find a number of changes that are small in magnitude but still statistically significant, illustrating how stable trading patterns are in the pre and post split periods.

3. Limit Order Book Results

The limit order book acts as a repository for liquidity that is augmented by floor brokers and the specialist (see Sofianos and Werner (1997)). As such, the limit order book will affect market

[10] Our results for individual trading activity probably understate the increase, since the decrease in NYSE market share suggests that there is additional order flow executing away from the NYSE. This order flow is most likely to have originated from individuals.

[11] In fact, Kavajecz (1999) and Goldstein and Kavajecz (1998) assume that limit order books are independent after 30-minute intervals and the increase in good until cancelled orders would bias against finding our results.

quality both through execution with incoming market orders (possibly reducing effective spreads) and by dampening price swings (possibly reducing temporary volatility). The effect of the limit order book depends on both the cumulative depth available in the book and the positioning of that depth throughout the book.

We recreate the limit order book as of noon each trading day following the methodology outlined in Kavajecz (1999) and employed by Goldstein and Kavajecz (1998), Corwin and Lipson (1999), and Harris and Panchapagesan (1999). While the details are clearly explained in Kavajecz (1999), the general approach is the following. From orders subsequently executed or cancelled we identify limit orders in existence at the start of our study period (the pre-book). We then add orders as they are submitted and remove orders that are either executed, cancelled or expire at the end of the day. What remains at a given point in time are the limit orders observed on the limit order book.

The first estimates of the limit order book may understate the depth in the book since some orders actually in the book at that time will not be executed or cancelled and will, therefore, not be recorded in our data. For this reason, we begin our statistical analysis of the limit order book after having processed ten days of order flow. In fact, as at the beginning of the pre-split study period, we process ten days of order flow before we begin our analysis of the post-split study period. In addition, we remove all orders left over from the pre-split time period for the following two reasons. First, this ensures that the method of construction is identical in the two time periods. Second, when a stock splits, limit buy orders are automatically adjusted by the split factor, but limit sell orders are unchanged. For example, a limit buy priced at $40 before a 2-for-1 split will be re-priced to $20, but a sell at $41 will not be changed. By starting our analysis

without any left over orders, we ensure that our results are not influenced by this asymmetric treatment of orders.[12]

Panel A of Table 4 presents our analysis of the quoted depth and total depth (depth available in the whole limit order book). With the quoted depth we also present the amount of depth provided by the specialist and trading floor (essentially the quoted depth less the depth available at the quoted price in the limit order book). We observe no change in either the quoted depth or the amount of depth provided by the specialist/floor. Of course, we must keep in mind that the proportional quoted spreads are wider in the post-split period, so that quoted depths are proportionally further from the mid-quote. This being the case, we might expect *greater* depth at these spreads, just as most researchers expected to see *less* quoted depth following a reduction in tick size (see Harris (1997), Bollen and Whaley (1998), Bacidore (1997), Goldstein and Kavajecz (1998), among others).

On the bid side of the limit order book we observe a substantial decline in share depth while there is no statistically reliable change on the ask side. In both cases, we observe an increase in the number of orders in the limit order book. The increase in the number of orders is consistent with the increased number of trades and orders documented in Table 2. Thus, even in the limit order book, we tend to observe smaller orders after a stock split.

Panel B of Table 4 presents the depth in the limit order book in terms of spreads - distances from the mid-quote at which various execution sizes can be completed trough the limit order book. We compute the difference between the limit price and the prevailing mid-quote for buy orders and the difference between the prevailing mid-quote and the limit price for sell orders. There are four spread measures and results are given separately for buys and sells:

[12] Our results are little changed if we include orders from the pre-split time period or if we include the first ten days in the pre- and post-split time periods. We believe the chosen method most accurately captures normal trading

Limit-Book Spread	Based on the best price in the limit order book, which is the highest buy and lowest sell order. This is the price one pays to execute the minimum depth available in the limit order book.
5,000 Share Spread	Based on the price at which the cumulative depth (total depth up to a given distance from the mid-quote) first exceeds 5,000 shares.
10,000 Share Spread	Based on the price at which the cumulative depth first exceeds 10,000 shares.
Average Spread	The share weighted average spread for all orders in the limit order book.

For the spread measures, the medians are calculated across firms since means are subject to numerous extreme values when there are few orders in the limit order book. The presented values are the means across firms of the median spreads by firm in the pre- and post-split time periods.

The limit order book is generally considered a measure of available liquidity. Clearly, the central concern of traders is the proportion of their invested capital that is lost to transaction costs rather than the dollar amount. In other words, selling down $1/2 is one thing for a $40 stock and another thing for a $20 stock. This would suggest that in regards to liquidity, proportional measures of depth make the most sense. Similarly, volatility is measured based on proportional price changes and, once again, proportional measures would make the most sense. However, it is also possible that trading strategies are conditioned on dollar price relations (i.e. submit a limit buy order one tick below the prevailing bid quote). For this reason that we present measures of depth in both dollar and proportional terms.

The results for the various limit book spreads are similar to what is observed for quoted spreads. In general, there is a decrease in the dollar spread, but a substantial increase in the

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activity.

spread as a proportion of the prevailing mid-quote. For example, on the bid side the 10,000 share spread declines from $1.30 to $0.98. However, as a proportion of the mid-quote, the 10,000 share spread increases from 2.42% to 3.32%.

While Table 4 characterizes depth by showing the distance to a given desired execution size, Table 5 characterizes depth by showing the available execution sizes at various prices. Specifically, Table 5 presents the cumulative and marginal depth in the limit order book at various distances from the middle of the quoted bid and ask.[13] The cumulative depth on the bid (ask) side is the total shares available equal to or above (below) the given cutoff level. Marginal depth is the depth available equal to or above (below) the given cutoff level and also below (above) the previous (smaller) cutoff level. In addition to cumulative depth, we show the change in cumulative depth and the change in marginal depth. We show only the change in marginal depth to conserve space, but marginal depth can be easily calculated from cumulative depth. [14]

Finally, we present results for both absolute dollar cutoffs and for split-adjusted (proportionally identical) cutoffs. As before, we choose to present our results on a post-split basis. Thus, for the adjusted cutoff results, the post-split cutoffs are identical and we adjust the pre-split cutoffs by the magnitude of the split. For example, with a two-for-one stock split the split-adjusted $1/8 cut-off is $1/8 after the split and $2/8 before the split. We include marginal depth along with cumulative depth to provide a picture of the distribution of depth throughout the book.

[13] While Goldstein and Kavajecz (1998) also use the mid-quote, it is possible to measure cumulative depth from either the bid or ask. In this study, since the bid-ask spread changes as a result of the stock split, we use the prevailing mid-quote.

[14] Since we observe some reduction in trading activity, both for total volume and for NYSE system volume, we also conducted our analysis based on depth as a proportion of the average trading activity in the pre-split and post-split time periods, respectively. Such an adjustment would also provide some picture of liquidity provided relative to liquidity demanded. Our results and conclusions are qualitatively similar, so we do not present that analysis.

Consider, for example, the bid side depth before the split at a cutoff equal to $2/8. There were 7,058 shares bid at that price or higher before the split and 9,619 after the split. The increase of 2,561 shares is significant. In addition, the change in the marginal depth was an increase of 1,458, which is also significant. In other words, an extra 2,561 shares were available up to $2/8 from the mid-quote, and 1,458 of those shares were at prices more than $1/8 away from the mid-quote. For the split-adjusted cutoffs, the shares available were (again) 9,619 after the split, but this represents a significant decline of 2,599 from the pre-split time period. There was no change in marginal depth at the adjusted cutoffs.

The striking result is that the cumulative depth increases at all points for absolute cutoffs and decreases at all points for split-adjusted cutoffs. The decline in adjusted cutoffs is quite large in magnitude. For example, on the bid side at a $1/8 cutoff, cumulative depth declines by 2,568 shares from a level of 7,443 – a decline of about 35%. As for the change in marginal depth, significant changes in accordance with the change in cumulative depth are observed at most cutoffs. The exception is the bid side for split adjusted cutoffs, where we observe a statistical decline only in the first cutoff. However, tests of medians (not reported) indicate significant reductions in marginal depth up to the $3/8 cutoff. In general, we observe that the reduction in depth is most pronounced, statistically and economically, closest to the mid-quote. This is consistent with the fact that about 70% of limit orders are placed within $1/4 of the mid-quote and this is where we might therefore observe the effects of changes in limit order activity.

4. Submission and Disposition of Limit Orders

In this section we address whether the changes in the limit order book are due to changes in the placement of limit orders or to changes in the execution of limit orders. In other words, limit order placements may be no different before and after a stock split, but changes in

execution patterns (possibly tied to changes in volatility) would alter the limit order book. The results also provide some additional insights into how trading strategies change as a result of a stock split.

Table 6 presents our results. Since the results are similar for buys and sells, we report results for the total sample of orders. The first part of Table 6 presents results for the location of limit orders. Results are provided for placements relative to the prevailing mid-quote and relative to the competing quote, where the competing quote is the bid for buy orders and the ask for sell orders. Results are given both for the average placement of orders and the proportion of orders placed at various locations. Placements are calculated so that positive values represent orders placed more aggressively, i.e. for buy orders we calculate the difference between the limit price and the prevailing mid-quote or competing quote, whereas for sells we calculate the difference between the prevailing mid-quote or competing quote and the limit price.

Relative to the mid-quote, we see clearly that limit orders are placed further away as a proportion of the price. Specifically, limit order are placed, on average, 33 basis away from the mid-quote before a split and this almost doubles to 60 basis points after the split. We also find, however, that limit orders are placed slightly closer, on average, in dollar terms. Before the split, limit orders are placed on average $0.184 away from the mid-quote and this decreases to $0.179 after a split. While significant, this reduction is small in magnitude.

We also show the proportion of limit orders placed no more than $1/8 away from the mid-quote (e.g. buy orders which are priced equal to or higher than $1/8 below the mid-quote). This analysis is provided in case changes in the average distances are being driven by changes in placements of orders far away from the prevailing quotes. After the split, the proportion or orders no more than $1/8 away from the mid-quote is almost 70%. We present two pre-split

comparisons – the identical dollar cutoff and a split-adjusted dollar cutoff. For the absolute cutoff, the proportion of orders is about 68% whereas for the adjusted cutoff, the proportion is almost 83%. These results provide a picture similar to the results for average placements - there is a substantial shift in orders away from the prevailing quotes if we examine proportional distances and a significant, but small, increase if we consider absolute cutoffs.

As for placements relative to the competing quote, the average placements are more than twice as far from the competing quote on a proportional basis after a split – 9 basis points before and 21 basis points after. In this analysis, even the dollar distance increases slightly, from $0.054 to $0.065. This is no doubt due, in part, to the reduction in the dollar quoted spread after a split (i.e. the quotes are closer to the mid-quote).

The proportion of orders place better than, equal to, or worse than the competing quote provide an interesting picture of trading strategies. Recent studies of order aggressiveness use a similar categorization of limit orders to characterize submission strategies. What we see is ample evidence that stock split alter trading strategies. Specifically, we find a substantial decrease in orders which are better than the competing quote, but increases in the proportion of limit orders at or $1/8 away from the competing quote. It seems that orders are clustering more frequently at the competing quote or close to it. This may reflect an increased willingness of limit orders to compete with the prevailing quote or if may simply result from fact that there are fewer points in the price grid at which to place orders and some of the orders that would have been better than the prevailing quote are now matching it.

Finally, Table 6 present results on the disposition of orders. We find no significant changes in fill rates or cancellation rates for limit orders. On average, limit orders are executed about 43% before a split and 42% after a split. Cancellation rates are about 38% ebfore a split

and 43% after a split. We do find, however, that it takes longer for both executions and cancellations to occur.

5. Execution Costs

Since fill rates are little changed by a stock split, but orders are placed proportionally much further from prevailing quotes, one might expect there to be a change in the execution costs associated with limit orders. Specifically, if limit orders are placed at less aggressive prices but still execute, then limit order execution costs should decline. These costs are examined in this section.

We follow Harris and Hasbrouck (1996) in measuring execution costs, but with one adjustment. They measure executions relative to the opposite side quote at the time the order is entered into superDOT. For example, they evaluate a buy order against the prevailing ask price since this is the price at which it would be expected to execute. Since quoted spreads change after stock splits, and this will affect the benchmark price, we use the mid-quote at the time an order reaches the superDOT system as our benchmark price. Thus, executions at the mid-quote in both the pre-split and post-split periods will be judged to provide identical execution, whereas with an opposite side benchmark, the post-split execution would be viewed more favorably since proportional spreads increase. Our definition is consistent with that used in Goldstein and Kavajecz (1998).

In general, the calculation of execution costs proceeds as follows. At the time an order is entered into superDOT, the prevailing mid-quote, p_q is recorded. The weighted average fill price, p_f, is calculated with weights equal to the shares executed. Multiple fill prices are possible since a single order may execute in parts and at different prices. The realized execution cost is the proportional cost expressed in basis points relative to p_q and adjusted so that both buys and

sells are expressed in such a manner that better executions provide lower costs: $Q*10000*(p_f - p_q)/p_q$, where Q is equal to one for buys and minus one for sells. Given our definition, market orders are likely to have positive costs (e.g. a market buy executes at the ask) and limit orders are likely to have negative costs (e.g. a limit buy sets the prevailing bid and executes against an incoming market order).

The above procedure is quite simple for executed orders and provides us a clear measure of realized trading costs. However, some limit orders are cancelled or expire, and an adjustment for these costs might be appropriate if we assume all traders are committed to executing their orders (see Perold (1988)). Following Handa and Schwartz (1996) and Harris and Hasbrouck (1996), we impute a cost to unfilled orders by assuming these orders are resubmitted as market orders. Specifically, the imputed cost combines the price movement from submission to cancellation or expiration plus the cost of a market order. We refer to the weighted-average of the realized costs for executed orders and the imputed costs for the remaining orders as the 'committed execution cost'.

It should be noted that the imputed cost of a cancelled or expired limit order, and therefore the unconditional expected cost of a limit order, represents a conservative (high) estimate of that cost for the following two reasons. First, when prices move away from a limit order, the order may be resubmitted as a new limit order rather than a market order. This would reduce the realized cost of the order since limit orders are less expensive. Second, a trader may not, in fact, wish to execute a limit order beyond a certain price and it may be inappropriate to impute any cost to such an order. We present both realized and committed costs to provide an estimate of the range of possible costs for participants.

We calculate realized execution costs for all orders. We also calculate the committed execution costs for limit orders. To provide a rough measure of execution costs across *all* orders, we calculate the weighted average realized and committed execution cost across these three order types. We acknowledge that these cost estimates are unconditional and that actual trading strategies will be complex and depend on market conditions. Furthermore, our analysis cannot capture the costs of trading strategies where large orders are broken up and submitted as smaller superDOT orders over time.[15] Despite these limitations, our estimates are likely to provide a more accurate and complete picture of the effects of stock splits on trading costs than what is obtained from a study of spreads alone. Furthermore, the evidence we present on costs should be considered jointly with the evidence we provide on the limit order book and submission strategies.

The results of our analysis of execution costs are shown in Table 7. The striking regularity in this analysis is the increase in realized costs for market orders and the reduction in realized costs for limit orders. For example, across all orders, the average execution cost for market orders rises from about 10 basis points to about 18 basis points. For limit orders, on the other hand, execution costs decline from a savings (negative cost) of about 19 basis points to a savings of about 31 basis. Marketable limit orders show little change in costs. Acknowledging the increased cost of non-execution, we observe a significant increase in the committed cost for limit orders.

We find no statistically significant change in the weighted average realized or committed execution costs across all orders. The reason, of course, is that the increased cost of executing a market order is offset by a decrease in the cost of submitting a limit order. This result might be

[15] We can, however, capture the costs of orders that are submitted at one point in time, but are executed in parts. This is one of the advantages of system data over Trade and Quote data.

driven, in effect, by the change in limit order pricing – limit orders are placed further from the mid-quote and traders who wish to execute against them must, therefore, pay a higher price.

We should note that the results for medians are, in this case, different – we observe a significant decline of 6 basis points in realized costs across all orders and a significant increase of 5 basis points for committed costs across all orders. Furthermore, we also observe a significant decline in realized executions costs and an increase in committed execution costs for buy orders. Most importantly, even if the increase in the committed costs (our conservatively high estimate) is reliably equal to 5 basis points, this is roughly half the 10 basis point increase in the effective half spread. Thus, our evidence provides a range of cost changes that varies from a savings, to an increase that is significantly below what is implied from an analysis of spreads.

6. Conclusion and Discussion of Results

We examine the limit order book and execution costs around stock splits to provide new evidence on the effects of stock splits on liquidity. Our central results are the following. First, the depth available in the limit order book at various dollar distances from the mid-quote increases while depth at proportional (split-adjusted) distances from the mid-quote declines substantially. Second, the change in the limit order book appears to be driven by changes in the placement of limit orders, and not a change in execution results. Third, we find evidence of a slight preference for limit orders after a stock spit. Fourth, we find little evidence that average execution costs increase after a stock split. And fifth, we provide direct evidence that more order flow originates from individuals after a stock split, and that individuals are more actively buying after a stock split.

Our results provide new insights into a number of long-standing stock split debates. The increases in spreads after stock splits has been viewed as strong evidence that liquidity declines

after a stock split. Our results suggest that this is true only for the most aggressive traders. Many individuals and institutions that purchase stocks after a split will not demand immediate execution and will submit limit orders to reduce execution costs.[16] For these traders, costs actually decline. While we do not examine market maker profits directly, the net effect on execution costs across all traders appears small. This suggests that even small gains to the firm (perhaps from increased visibility) could justify a stock split.

A number of studies document increases in volatility after a stock split. An important question is whether this is the result of a change in the information environment or whether is related to microstructure phenomena. Koski (1998) demonstrates that the increase is not due to measurement problems related to wider spreads. However, our results indicate that a contributing factor may be changes in the limit order book. If prices must move proportionally further after a split to encounter the same trading interest, then volatility could increase.[17]

Building on the Brennan and Hughes (1991) observation that stock splits increase broker commissions and might motivate brokers to promote a stock, Angel (1997) and Schultz (1998) suggest that the wider spreads that accompany stock splits might increase brokerage profits and provide additional incentive to promote stocks. Many of the changes we observe in order flow are consistent with brokers promoting stocks to individuals and corroborate the indirect evidence in Schultz (1998). However, our results on execution costs suggest that the additional profits to brokers from increased spreads may be of limited significance for NYSE stocks.

[16] Harris (1994b) suggests that limit orders might be used as part of a strategy for purchasing stocks, even if the individual is a motivated buyer.

[17] Koski (1998) also shows that volatility increases weekly horizons, suggesting that changes in depth would provide only a partial explanation for the increase in volatility.

Harris (1991, 1994b, 1996), Glosten (1994), and Seppi (1997) argue that wider tick sizes encourage the submission of limit orders rather than market orders.[18] In addition, Harris (1994a), Anshuman and Kalay (1993), and Angel (1997) suggest that a stock's normal trading range may, in fact, be determined by an optimal *relative* tick size (tick size as a proportion of price). Since stock splits, among other things, increases the *relative* tick size by reducing prices, it would be natural to wonder whether our evidence on stock splits might provide additional insights on the link between tick size and limit order activity. In practice, what we can conclude is quite limited. We do find that there is an increase in the proportion of limit orders after a stock split and this provides support for the theories mentioned above. However, fact that we are observing a change in relative, rather than absolute, tick size makes interpretation of the rest of our evidence along these lines difficult.

The reason is the following. Trading interest is likely to be related to the proportional distance from prices since the return to holding a security will be related to proportional costs of execution. In other words, we expect there to be increasing demand as we move proportionally further from the mid-quote. On the other hand, it is quite plausible that traders may condition execution strategies on tick sizes since many institutional trading constraints faced by market participants (particularly market makers) are tick based. For example, a trader cannot obtain execution priority without improving on an existing price by at least one tick. These two possibilities, both reasonable, confound our ability to draw strong conclusions from our evidence. Consider the results on depth a dollar distances from the mid-quote. This increase in depth means little if we take a demand schedule view since each tick is proportionally further

[18] The central intuition is that coarse pricing grids (large relative tick sizes) prevent floor traders from jumping ahead of standing limit orders by making it costly to improve upon the limit order's price. Anshuman and Kalay (1998) show that discrete prices generate profits for market makers, reduce the value of private information, and may

from the mid-quote after a stock split, but the results might support an increase in limit order preferences if we take a tick-based trading strategy view.

These potential differences are particularly important when we consider how our results compare to studies of the reduction in absolute tick size by the NYSE in June of 1997. In an analysis similar to the one presented in this paper, Goldstein and Kavajecz (1998) find that depth in the limit order book is reduced. Bolen and Whaley (1998) provide evidence that spreads and quoted depth both declined around this event, while Jones and Lipson (1999) find that institutional trading costs increased, particularly for liquidity demanders. Depending on whether absolute or relative distances are chosen to benchmark depth in the limit order book, our results provide either additional support or a puzzling contrast to the analyses, respectively. Clearly, additional research distinguishing between dollar and relative price changes would add to our understanding of why we observe the changes in market quality we document in this study.

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reduce the trading costs of liquidity traders. In contrast, Bacidore (1999) shows that discrete pricing grids generate profits for market makers, increases the value of private information, and increases trading costs for liquidity traders.

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Table 1
Sample Size and Characteristics

Number of firms and descriptive statistics, by split category, used in our tests. The sample includes all stock splits in 1995 and 1996 of NYSE common stocks where the split was at least two-for-one and there were at least five days in the pre-split and post-split analysis periods with system orders. The pre-split time period is sixty days prior to the split ex-date and the post-split period is the sixty days after the split ex-date. Market capitalization, shares outstanding and pre-split price (closing mid-quote) are given as of the day prior to the split ex-date. The post-split price (closing mid-quote) is given for the ex-date. The highest price and lowest price in the sample are given below the average price. NYSE daily share volume is the adjusted to the post-split basis and is the average over the 120-day study period.

	Full Sample	**2-for-one**	**Greater Than 2-for one**
Split Characteristics			
Number of Splits	158	149	9
Average Split	2.09	2.00	3.50
Firm Characteristics			
Market Capitalization ($ thous.)	6,396	6,149	10,475
Shares Outstanding	79,518	79,306	83,045
NYSE Daily Share Volume	522,622	491,665	1,105,353
Pre-Split Price ($)	68.50	65.20	123.22
	(26.88-226.50)	(26.88-158.81)	(62.38-226.50)

Table 2
Analysis of Market Quality and Trading Activity

Market quality and trading activity summary statistics. The quoted half-spread is one half the difference between the ask and bid, effective half-spread is absolute value of the difference between the execution price of a trade and the mid-quote at the time of execution. The standard deviation of returns is calculated across daily (close to close) returns and daytime volatility is the average of the squared daytime excess returns (open-to-close return less the mean open-to-close return over the study period). All share values are adjusted to a post-split basis. Total buying and selling activity is obtained from the TAQ data sets. NYSE system trading activity is obtained from NYSE system order data. NYSE market share is the ratio of NYSE executed activity to total activity. The NYSE system proportion is the ratio of system share volume to twice the total executed NYSE share volume. Tests of significance are based on the distribution across firms of the pair-wise difference between pre and post split means and medians except for tests on the standard deviation of returns, which are based on the univariate *t* tests (means) and Wilcoxon signed rank tests (medians) comparing the distribution of the pre and post split sample values.

	Mean		Median	
	Before	**After**	**Before**	**After**
Panel A: Market Quality				
Dollar Quoted Half-Spread ($)				
Dollar Effective Half-Spread ($)				
Proportional Quoted Half-Spread (%)				
Proportional Effective Half-Spread (%)				
Standard Deviation of Returns (%)				
Daytime Volatility (%)				
Panel B: Total Daily Trade Activity				
NYSE Trading Activity				
Share Volume				
Number of Trades				
Dollar Volume ($ thousands)				
NYSE Market Share				
By Dollar Volume (%)				
By Number of Trades (%)				
Panel C: NYSE System Daily Executed Order Activity				
Share Volume	*All Orders*			
	Buys			
	Sells			
Number of Orders	*All Orders*			
	Buys			
	Sells			
Dollar Volume ($thou.)	*All Orders*			
	Buys			
	Sells			
NYSE System Proportion (%)				

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 3
Distribution of System Orders Across Order Types

System daily order submissions by order type and as a proportion of total order submissions. Also presented are the daily share volume for each order type originating directly from individual traders along with (1) individual trader volume in each category as a proportion of total order volume within each order type, and (2) individual trader volume in each category as a proportion of all individual orders. Finally, we present the daily share volume of limit orders that do not expire at the end of a trading day, both in shares and as a proportion of limit orders. Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split mean values.

	Buys		Sells	
	Before	**After**	**Before**	**After**
All Orders				
Total				
Individuals				
Market Orders				
Total				
Percent of All Orders				
Individuals				
Percent of Market Orders				
Percent of All Individual Orders				
Marketable Limit Orders				
Total				
Percent of All Orders				
Individuals				
Percent of Marketable Limit Orders				
Percent of All Individual Orders				
Limit Orders				
Total				
Percent of All Orders				
Individuals				
Percent of Limit Orders				
Percent of All individual Orders				
Good Until Cancelled				
Percent of Limit Orders				

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 4
Analysis of Limit-Book Spreads

Limit order book depth in shares at 12:00 p.m. before and after the stock split calculated as in Kavajecz (1999). The quoted depth and specialist or floor contribution to quoted depth (quoted depth less the shares in the limit order book) are also given. There are four limit-book spread measures. Spreads are the difference between the prevailing mid-quote and limit price for buy orders and the difference between the limit price and prevailing mid-quote for sell orders. The limit book spread is calculated from the best limit book price (highest bid or lowest ask), the 5,000 and 10,000 share spreads are the calculated from the prices at which 5,000 and 10,000 cumulative shares are available in the limit order book, respectively, and the average spread is the share weighted average spread for all orders on the limit order book. All share values are given on a post-split basis. The given values are the means across firms where firm values are the medians across the fifty days prior to the split (before) or fifty days starting ten days after the split (after). Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split values.

PANEL A: Quoted Depth and Total Limit Order Book Depth

		Quoted Depth		**Limit Book**	
		Quoted Depth	*Specialist And Floor Contribution*	*Total Shares*	*Number of orders*
Bid Side	*Before*	5,240	3,266	86,851	50
	After	5,556	3,309	60,635***	77***
Ask Side	*Before*	6,765	4,512	55,598	24
	After	6,791	4,385	59,295	38***

PANEL B: Limit-Book Spreads

Dollar Half-Spreads ($)		Limit Book Spread	5,000 Share Spread	10,000 Share Spread	Average Spread
Bid Side	*Before*	0.14	0.83	1.30	2.32
	After	0.09	0.62	0.98	1.69
	Change	-0.05***	-0.21**	-0.32**	-0.63***
Ask Side	*Before*	0.13	0.52	0.86	1.73
	After	0.10	0.53	0.84	1.47
	Change	-0.03***	+0.01	-0.02	-0.26***
Proportional Half-Spreads (%)					
Bid Side	*Before*	0.27	1.57	2.42	3.96
	After	0.34	2.17	3.32	5.20
	Change	+0.07***	+0.60***	+0.90***	+1.24***
Ask Side	*Before*	0.25	1.03	1.62	2.98
	After	0.35	1.99	3.09	5.06
	Change	+0.10***	+0.96***	+1.47***	+2.08***

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 5
Analysis of Limit-Book Depth

Limit order book depth in shares at 12:00 p.m. before and after the stock split calculated as in Kavajecz (1999). The limit order book is expressed as the cumulative depth up to (and including) various dollar distances (cutoffs) from the prevailing quoted spread midpoint, as well as the marginal depth from the previous cutoff up to (and including) the given cutoff. Depth is given for absolute dollar cutoffs in the pre- and post-split time periods and for split-adjusted dollar cutoffs in the pre-split time period. All share values are given on a post-split basis. The given values are the means across firms where firm values are the means across the fifty days prior to the split (before) or fifty days starting ten days after the split (after). Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split values.

Absolute Cutoffs	1/8	2/8	3/8	4/8
Bid Side				
Cumulative Depth Before	3,772	7,058	9,608	11,664
Cumulative Depth After	4,875	9,619	13,154	16,021
Change in Cumulative Depth	+1,103***	+2,561***	+3,546***	+4,357***
Change in Marginal Depth	+1,103***	+1,458***	+985***	+811***
Ask Side				
Cumulative Depth Before	4,642	8,742	12,088	14,650
Cumulative Depth After	5,634	11,082	14,991	18,190
Change in Cumulative Depth	+992***	+2,340***	+2,903***	+3,540***
Change in Marginal Depth	+992***	+1,348***	+563***	+637***
Split-Adjusted Pre-Split Cutoffs	1/8	2/8	3/8	4/8
Bid Side				
Cumulative Depth Before	7,443	12,218	15,610	18,171
Cumulative Depth After	4,875	9,619	13,154	16,021
Change in Cumulative Depth	-2,568***	-2,599***	-2,456***	-2,150***
Change in Marginal Depth	-2,568***	-31	+143	+306
Ask Side				
Cumulative Depth Before	9,160	15,384	19,743	23,070
Cumulative Depth After	5,634	11,082	14,991	18,190
Change in Cumulative Depth	-3,526***	-4,302***	-4,752***	-4,880***
Change in Marginal Depth	-3,526***	-776**	-450**	-128

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 6
Analysis of Limit Order Submission and Disposition

Summary statistics on the location and execution results for limit orders. The location of limit orders and the proportion of limit orders placed at given locations are given relative to both the prevailing mid-quote and the prevailing competing quote, where the competing quote is the bid (ask) for limit buy (sell) orders. Locations are given both in dollars and basis points. The proportions of limit orders placed at given dollar calculated for both absolute dollar and split-adjusted (proportional) distances. Disposition information includes the proportion of all limit orders which are executed or cancelled (the remaining orders expire at the end of the day) and how long, on average, it takes for execution or cancellation to occur. Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split values.

	Before	**After**
Location of Limit Orders		
Location Relative to Mid-Quote:		
Distance from mid-quote (basis points)	33bp	60bp***
Distance from mid-quote (dollars)	$0.184	$0.179**
Proportion no more than $1/8 (absolute) from the mid-quote	68.1%	69.7%***
Proportion no more than $1/8 (adjusted) from the mid-quote	82.6%	69.7%***
Location Relative to Competing Quote		
Distance from competing-quote (basis points)	9bp	21bp***
Distance from competing-quote (dollars)	$0.054	$0.065**
Proportion better than competing quote	32.2%	25.9%***
Proportion equal to competing quote	42.7%	46.9%***
Proportion placed $1/8 below competing quote	8.2%	10.8%***
Disposition of Limit Orders		
Fill Rate (Proportion of Limit Orders Which are Executed)	42.8%	42.3%
Seconds to Execution	1,323	1,460***
Cancellation Rate (Proportion of Limit Orders Which are Cancelled)	37.5%	42.6%
Seconds to Cancellation	2,087	2,243***

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 7new
Analysis of Odd Lot Orders

Summary statistics on the volume of system orders partitioned by size. Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split values.

Size of Order is:	**Category 1** Odd-Lot both Pre and Post split	**Category 2** Odd-Lot Pre-Split but not Post Split	**Category 3** Always Above Odd-Lot, but below 1000 Shares Post Split	**Category 4** Above 1000 Shares Post-Split
All Orders				
Pre-Split				
Post Split				
Change				
Individuals				
Pre-Split				
Post Split				
Change				
Institutions				
Pre-Split				
Post Split				
Change				

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 7
Analysis of Execution Costs

Mean execution costs (in basis points) of orders. The committed cost for all orders and limit orders assumes that limit orders that are cancelled or not executed are converted to market orders. The cost of such orders includes the cost of price movements prior to conversion to a market order and the average costs of executing a market order. Realized costs are the costs for orders that are executed. Tests of significance are based on a *t*-test of the distribution across firms of the pair-wise difference between pre and post stock split values.

	All Orders		**Market Orders**		**Limit Orders**	
	Realized	*Committed*	*Market*	*Marketable Limit*	*Executed*	*Committed*
All Orders						
Before						
After						
Change						
Buy Orders						
Before						
After						
Change						
Sell Orders						
Before						
After						
Change						
Before						
After						
Change						
Before						
After						
Change						
Before						
After						
Change						

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Table 8
Changes in Execution Costs by Various Quartiles

Mean execution costs (in basis points) of orders. The committed cost for all orders and limit orders assumes that limit orders that are cancelled or not executed are converted to market orders. The cost of such orders includes the cost of price movements prior to conversion to a market order and the average costs of executing a market order. Realized costs are the costs for orders that are executed. The values below are the median change in costs for firms in each partition. Tests of significance are based on the Wilcoxon signed rank test.

	All Orders		**Market Orders**		**Limit Orders**	
	Realized	*Committed*	*Market*	*Marketable Limit*	*Executed*	*Committed*
By Daily Volume						
1: Smallest						
2						
3						
4: Largest						
Prob > | Z |						
By Effective Spread						
1: Smallest						
2						
3						
4: Largest						
Prob > | Z |						
By Price						
1: Smallest						
2						
3						
4: Largest						
Prob > | Z |						
By the Proportion of Quotes at the Minimum Spread						
1: Smallest						
2						
3						
4: Largest						
Prob > | Z |						

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level