Liquidity, Market Structure, and Stock Splits

David Michayluk*
School of Banking and Finance
University of New South Wales
Sydney, NSW 2052 Australia
Phone (61) 2 9385-5861
Fax (61) 2 9385-6347
Email d.michayluk@unsw.edu.au

Paul Kofman
School of Finance and Economics
University of Technology – Sydney
Sydney, NSW Australia
Phone (61) 2 9514-7728
Email paul.kofman@uts.edu.au

Comments Appreciated
First Version April 10, 2000
This Version July 12, 2001

*Corresponding author.

We wish to thank Katrina Ellis, Thomas Henker, Cyndi McDonald, Karyn Neuhauser, Laurie Prather, Jay Ritter, Kris Webster and Li-Anne Woo and seminar participants at the University of Western Australia, the University of Missouri-Columbia and George Washington University for helpful comments. Paul Fowler provided invaluable research assistance. All errors remain the responsibility of the authors.

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Enhanced liquidity is one possible motivation for stock splits but empirical research frequently documents declines in liquidity following stock splits. Despite almost thirty years of inquiry, little is known about all the changes in a stock's trading activity following a stock split. We examine how liquidity measures change around more than 2,500 stock splits and find a pervasive decline in most measures. Large stock splits exhibit a more severe liquidity decline than small stock splits, especially on Nasdaq. We also examine a longer time period around stock splits and find that the differences between small and large stocks may be short-lived. Following the 1997 changes in order handling rules and reduction in tick size, liquidity declines following stock splits continue, however, the declines are not as severe on Nasdaq, suggesting the change in order handling rules may have been effective.

Liquidity, Market Structure, and Stock Splits

Stock splits have confounded financial economists for years because they merely increase the number of outstanding shares without providing any new funds to the company and without changing the shareholders' claims on the firm's assets. Nevertheless, companies bear real costs to undertake these transactions [1]. The cosmetic change does appear to enhance firm value as positive abnormal returns are observed at stock split announcements [2]. Researchers have explained this phenomenon using five hypotheses, some of which suggest that there are liquidity changes following the stock split. In this paper we study the physical stock split that occurs, on average, twenty-five days after the announcement. This event is not associated with a news event, but is associated with a new trading structure, one where the price level is lower and the number of shares outstanding is increased. Evidence of liquidity shifts during this event can be used to assess explanations of abnormal returns around stock split announcements.

The study of the impact of stock splits on liquidity has become more important as the number of firms declaring stock splits has increased. The total number of stock splits with a split factor of at least 5 for 4 (or a 25% increase in the number of shares outstanding) has risen by almost 300% from 245 in 1990 to 724 in 1998. While the number of publicly traded firms has also increased during the 1990s bull market, the increase is more modest and does not explain the increase in the number of stock splits. Fama and French (2000) find that firms are becoming less likely to pay dividends and consequently firms may be relying on stock splits to manage the share price if stock repurchases are driving share prices higher. Furthermore, firm characteristics are inextricably linked to the exchange on which the firm's stock is trading [3].

The five hypotheses developed in the literature to explain the positive response to stock split announcements are: signaling, trading range, liquidity, tax timing and tick size. Brennan and

[1] Besides administrative costs, some exchanges, including the NYSE and Nasdaq, charge fees based on the number of shares outstanding.

[2] See Fama, Fisher, Jensen and Roll (1969), Grinblatt, Masulis and Titman (1984), Lamoureux and Poon (1987) and others.

[3] Besides differences due to a dissimilar market structure and trading mechanisms, exchanges may even attract a specific type of stock. For example, the Nasdaq exchange may be more flexible than the NYSE in their listing requirements, thereby attracting companies with more growth prospects (and higher potential for using stock splits in lieu of dividends).

Copeland's (1988) signaling model suggests that managers may communicate their positive information to the market by means of a stock split. The trading range hypothesis identified in a survey of managers conducted by Baker and Gallagher (1980), and, also reported in Copeland (1979), suggests that there is an optimal price range in which a stock should trade. Consequently, when stock prices are too high, a split should be undertaken so that small investors can afford to buy the stock[4]. The liquidity hypothesis was identified by Dolly (1933) and supported by a survey of managers. Specifically, Baker and Powell (1993) find that managers view liquidity improvements second only in importance to the trading range hypothesis. One interpretation of this reference to liquidity is that the number and diversity of shareholders increases following a stock split. The trading range and liquidity hypotheses are not necessarily mutually exclusive explanations, however, Easley, O'Hara and Saar (2001) suggest that individuals may have a preference for a specific trading range because liquidity is higher in that price range. The tax timing hypothesis offered by Lamoureux and Poon (1987) suggests that the trading volume will increase and the tax-option value of the stock will increase following a stock split. Recently, Harris (1996) and Angel (1997) suggest that stock splits may be used to position a stock's price so that the tick size is optimal with regards to the trade off between higher costs to investors and lower costs to liquidity suppliers such as market makers and limit order providers. An increase in the number of liquidity suppliers will then be reflected in higher liquidity for the stock. Of these five hypotheses, the trading range, liquidity, tax timing and tick size hypotheses imply that liquidity should increase following a stock split, while the signaling hypothesis implies there is no change following the stock split.

While liquidity is easily recognized it is "not so easily defined" [O'Hara (1997, p 216)]. One general definition of common stock liquidity is the "accommodation of trading with the least effect on price" [O'Hara (1997, p 217)]. Using proxies for liquidity, empirical evidence on the impact of stock splits on liquidity is mixed. Proportional bid-ask spreads have been found to either increase (Copeland (1979), Conroy, Harris and Benet (1990) and Desai, Nimalendran and Venkataraman (1998)) or stay the same (Murray (1985)). Using trading volume as a proxy for liquidity, Copeland (1979), Lamoureux and Poon (1987), and Conroy, Harris and Benet (1990)

[4] Alternatively, small investors could purchase a smaller number of shares, but at the time that this hypothesis was developed, commissions were larger for transactions that were not in blocks of one hundred shares.

report that there is a decrease in split-adjusted volume following a stock split while Murray (1985) and Lakonishok and Lev (1987) report no change in volume. Share price volatility, as a measure of liquidity, has been shown to increase following a stock split (Ohlson and Penman (1985), Dravid (1987), Lamoureux and Poon (1987), Conroy, Harris and Benet (1990), Dubofsky (1991), Desai, Nimalendran and Venkataraman (1998) and Koski (1998)). The number of trades per day has been found to increase following stock splits (Muscarella and Vetsuypens (1996), Kryzanowski and Zhang (1996) and Desai, Nimalendran and Venkataraman (1998)). Moreover, Desai, Nimalendran and Venkataraman (1998) find that there is a significant decrease in the average number of shares per trade following a stock split and Lakonishok and Lev (1987) find an increase in the number of shares traded as a percentage of the outstanding shares following stock splits.

Other literature uses proxies that are more difficult to calculate. For example, Schultz (2000) finds that the number of small orders increases following a stock split and Lamoureux and Poon (1987) and Maloney and Mulherin (1992) find an increase in the number of shareholders. Maloney and Mulherin (1992) also find higher dollar volume and more trades after stock splits. Alternatively, Lipson (1999) finds that the depth available at dollar-distances away from the bid-ask spread midpoint increases, but at split-adjusted percentage distances, the depth actually decreases. These mixed results suggest that simple statistics may not be sufficient to evaluate changes in liquidity.

This paper provides a comprehensive picture of the microstructure changes to common stock liquidity following stock splits. In particular, we examine the impact of stock splits on various liquidity measures around stock splits that occurred over a 6 year period. We also examine the effect of the magnitude of the stock split on liquidity since liquidity issues involving stock splits may be different for different sizes of stock splits. We analyze the two most frequent stock split magnitudes separately in case there are different motivations for different sizes of stock splits (Elgers and Murray (1985)).

Further, we evaluate how market structure affects the impact of stock splits on liquidity by examining how measures of liquidity differ across the New York Stock Exchange (NYSE), the

American Stock Exchange (Amex) and Nasdaq. The market structure may influence the statistics. Specifically, the method for recording volume on the Nasdaq exchange differs from the NYSE and the Amex, thus any amalgamation of statistics may blur significant distinctions. Even the similar specialist structures of the NYSE and the Amex may have different implementation or may attract stocks with different trading characteristics and again,any analysis that does not separately analyze each exchange may lead to false conclusions. Finally, we ascertain the liquidity impact of the 1997 structural change when the order handling rules and the minimum tick size were altered.

The remainder of this paper is organized as follows. In Section 1, existing liquidity proxies are identified and their interrelationships are discussed. Estimates of liquidity measures around stock splits are reported in Section 2. Conclusions are contained in Section 3.

1. Liquidity proxies

Empirical proxies for liquidity can be categorized as either measures of friction or activity, reflecting the two dimensions of liquidity. Friction measure classifications follow Demsetz (1968), Grossman and Miller (1988) and recently, Stoll (2000), where friction is identified as the price concession for immediacy. In contrast, activity measures reflect the extent of trading. These two dimensions have opposing directional impacts on liquidity. Specifically, an increase in a friction measure indicates reduced liquidity, while an increase in an activity measure indicates increased liquidity. Table 1 identifies 31 liquidity measures, and provides the method of calculation as well as references to selected studies that have considered the associated liquidity proxy.

A. Friction Measures

Friction measures can be categorized as bid-ask spread measures, price measures or return measures. Bid-ask spread measures reflect the cost of transaction in the market. Quoted bid-ask spreads are one of the most commonly used liquidity measures and also provide a proxy for execution costs[5]. However, this measure is not without its critics. Grossman and Miller (1988)

[5] As a measure of execution costs, the bid-ask spread has been the primary measure of concern in the recent Nasdaq implicit collusion controversy. See Christie and Schultz (1994) and Christie, Harris and Schultz (1994).

and Lee, Mucklow and Ready (1993) argue that the quoted bid-ask spread is a noisy and inadequate measure of liquidity since a large number of transactions take place at prices other than the quotations[6]. The percentage spread more accurately reflects the percentage cost of trading, by relating the size of the spread to the share price. This maybe particularly relevant if the minimum tick size is the constraint. The effective or realized bid-ask spread has also been used as a liquidity proxy (Hasbrouck and Schwartz (1988) and Hasbrouck and Seppi (2000)). Price improvement contained in the effective spread versus the quoted spread may be the result of floor traders ability to identify the trading party and thereby reduce information asymmetry and obtain a better price. Trades inside the spread may also be the result of limit orders that the specialist wants to satisfy without altering the quoted bid-ask spread. These scenarios suggest that the effective spread may not be the best measure of liquidity since it may not fully account for asymmetric information effects.

The share price can also be considered to be a friction measure since it may be an indicator of liquidity according to the trading range hypothesis. Also, as mentioned above, the share price may force the percentage bid-ask spread larger than necessary if the minimum tick size is constraining. Two additional proxies that measure the range of prices and range of quote midpoints within a trading day are also included in the price measure subcategory.

Various return measures are also considered to be a friction measure subcategory. Intraday returns relative to the number of transactions, as well as intraday return volatility measures can be used as indicators of fluctuations in liquidity during the trading day.

B. Activity Measures

Activity measures reflect the extent of trading. Measures of depth reflect the ability to trade at the given bid and ask quotation. Explanations of changes in quoted liquidity may hinge on the amount of quoted depth used to fill the trade. Kavajecz (1999) suggests that for most securities, quotations convey public trading desires and as market orders deplete the quoted depth, specialists move quotations to the nearest price containing additional standing volume. If floor brokers provide standing volume then any prior quotations will not be depleted by trading, and

[6] See Huang and Stoll (1996) and Petersen and Fialkowski (1994).

there will be less of a change in liquidity. Depth measures include separate bid and ask depth measured as the number of shares and the dollar value of the quoted depth. Additionally, the depth can also be converted to a log measure, or divided by the spread to capture both dimensions of liquidity. Some authors combine the spread and depth to obtain a measure of liquidity. Lee, Mucklow, and Ready (1993) suggest that both spread and depth are necessary to infer contemporaneous changes in liquidity. They argue that changes in spread or depth alone could reflect shifts along a liquidity supply curve, as opposed to shifts in the curve itself, as judged from a combined analysis of spread and depth changes. We include this combined measure (Depth/Spread) as an activity measure, since the calculation has the activity measure as the numerator.

Barclay, Kandel and Marx (1998) emphasize activity measures, such as volume, as better indicators of liquidity than price discounts. Volume of trading has been measured in a variety of ways, including the number of shares traded, dollar volume of shares traded[7], and the number of transactions[8]. Additionally, Marsh and Rock (1986) calculate a liquidity statistic based on the number of shares traded per unit of return.

Size measures are another subcategory of activity measures and reflect the magnitude of the firm, the number of shares or the transaction dollar value. Haugen (1999) suggests that liquidity differences affect stock prices by making some stocks more costly to trade than others. He suggests that there is a family of liquidity factors including market capitalization and trading volume divided by market capitalization. Datar, Naik and Radcliffe (1998) suggest that the number of shares traded by itself is not a sufficient statistic for the liquidity of a stock since it does not take into account the differences in the number of shares outstanding or the shareholder base. They use the turnover rate, measured as the number of shares traded divided by the number of shares outstanding in that stock. We also include the average transaction size, the extent of the trading that occurs within the bid-ask spread, and the size of the first and last transaction each day.

[7] See Loughran (1997).

[8] Jones, Kaul and Lipson (1994) suggest that *information asymmetry* is better measured by the number of transactions. Barclay and Warner's (1993) stealth trading explanation also suggests that volume alone is not sufficient as a gauge of activity since informed traders will hide large trades by splitting them up.

The existing literature has identified many liquidityproxies, but it is uncertain how each measure changes around an event expected to impact on liquidity. In the next section we estimate these measures in the days surrounding a stock split.

2. Empirical estimates of liquidity proxies

Intraday quote and transaction data is obtained from the Trades and Quotes (TAQ) database of the NYSE after obtaining stock split information from the Center for Research in Security Prices (CRSP) database and online financial information[9]. We exclude those stocks that changed exchanges during the forty-day period before or after the stock split. Also removed are those stocks with a disagreement in the stock ticker symbol between the TAQ and CRSP databases. These filters reduced our sample size by less than 5%. We examine 1,667 (1,122) stock splits that occurred in the period March 1993 to December 1999 with a split factor of two for one (three for two). Figure 1 shows the frequency of stocks splits each year across the three exchanges. Of the exchanges, Nasdaq has a total of1,830 stock splits, followed by NYSE with 824 splits and then the Amex with 135 splits.

We chose stock splits with a factor of two for one and three for two because these are the most frequent stock split ratios and previous studies indicate that the motives of companies issuing these stock splits may differ. For instance, Elgers and Murray (1985) suggest that small (less than a two for one) splits may be liquidity driven, while large (at least a two for one) splits may be undertaken to signal positive information. Furthermore, if the preferred trading ranges identified by Baker and Powell (1992) differ between stock splits, then we might expect small splits to occur at a lower average price than large stock splits, thereby confounding any tests that do not analyze the samples separately. Consistent with the literature, we hereafter refer to the two stock split groups as small (three for two) and large (two for one) splits[10].

Estimates of each liquidity measure are calculated for each trading day. The method of determining the daily estimate depends on whether the measure is calculated using trade or quote data. When using trade data we estimate each liquidity measure per stock by first determining

[9] We use E*Trade as well as Briefing.com to confirm stock split details.

the daily mean by weighting each trade by the size of thetransaction. When using quote data, we first estimate the daily mean per stock by weighting each estimate using the length of time (in seconds) that the quote was outstanding[11]. Then we compute the mean liquidity measures across stocks. Details of the calculation of each liquidity measure can be found in Table 1.

In addition to reporting the raw means across stocks both before and after stock splits for small and large stock splits, we also calculate an adjusted unit ratio of each measure. This is the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. If liquidity isunchanged following the split, this ratio will equal one. For example, since the number of shares doubles following a two for one stock split, volume following the split is divided by two. Most measures are adjusted by dividing or multiplying by 2 (or 1.5 in the case of three for two stock splits). This adjusted unit ratio facilitates any comparison of how measures change around stock splits, since we can see the relative change compared to what we would expect if no other trading characteristics were altered.

The adjusted unit ratio reported is the mean of the adjusted unit ratio for each measure, and there are some stocks with very large ratios, resulting in a distribution that is highly positively skewed. The reported mean ratio values can therefore be somewhat unreliable as a measure of distributional tendency. Thus, we test whether the adjusted unit ratios are statistically different from 1 by using a non-parametric Wilcoxon signed rank sum test. The signed rank sum test is the appropriate test to use since we compare two populations of quantitative data drawn from a matched pairs (before/after split) experiment. Because of nonnormality, the t-test for the mean adjusted unit ratio is not appropriate. The Wilcoxon test indicates if the measure being tested is statistically significantly larger or smaller than 1. We report this information by placing the levels of significance to the left or right of the measure, indicating the measure is significantly

[10] No other stock split magnitudes are included to ensure an adequate sample size within each group of stock splits.
[11] For the percentage bid-ask spread, we test for robustness of our averaging technique by estimating themean using three other weighting methods. We obtain a daily estimate by examining the final quote of the day since this was the only quote available in early bid-ask spread studies of stock splits. We also weight the observations using the depth of the quotes, and finally using the size of the transactions that occurred while each specific quote was outstanding.

smaller or larger than 1, respectively. Note that due to the significant non-normality, a mean adjusted unit ratio larger than one can still lead to a Wilcoxon outcome smaller than one! We also compare adjusted unit ratios of the small and large stock splits by performing the non-parametric Kruskal-Wallis rank test for equality of populations. As for the signed rank sum test, we test population locations, instead of population means. The samples are now, however, independent and hence we can use this test for completely randomized design.

We have three different sample periods for which we examine the data. The first two periods are the one-day period and the twenty-day period before and after the stock splits. The third sample period is a five-day period excluding the week before and after the stock split resulting in a sample period from (trading) day –10 to day –6, and (trading) day +6 to day +10. These three sample periods ensure we have the period immediately surrounding the split, a longer period surrounding the split and a longer period, excluding any immediate effects, respectively.

A. NYSE One-Day Window Estimation Period

Using the one-day estimation interval before and after the stock split, Table 2 reports the mean liquidity measures for stocks on the NYSE. In general, friction measures increase following stock splits, indicating a decrease in liquidity. Of the bid-ask spread measures, the mean adjusted ratio increase is larger for large stock splits. The log of the quoted-slope measure (LQuoteSlope) is the only exception, showing a significantly larger increase, and larger reduction in liquidity, for small stock splits. The Kruskal-Wallis test indicates that following small and large stock splits, adjusted bid-ask spread ratios are statistically different.

Of the price measures, the adjusted ratios of the price (Price) of the stock are significantly different from 1. The measure of the daily price range (HiLo) shows that the absolute price range declines from $1.52 to $1.22 following large stock splits, but on an adjusted basis this is actually a 61% increase[12]. The mean adjusted ratio shows that the mean of the individual stock adjusted ratio is even higher, reported at 2.10. This is indicative of the positive skewness in the empirical distribution of adjusted ratios. Following small stock splits, the daily price range stays approximately the same (around 90 cents), but this also represents an increase. Evaluating the

[12] $1.22 multiplied by 2 divided by $1.52 equals 1.61.

midpoint of the bid-ask spread to calculate the daily price range (HiLoMdpt) demonstrates a larger increase in the measures, indicating a more pervasive decrease in liquidity. For the decline in liquidity observed in the price measures, there is no statistical difference between price measures for small and large stock splits.

Most of the return measures exhibit significant increases and indicate a decline in liquidity. One measure, the intraday standard deviation of the midpoint of the bid-ask spread (IntraSDMdpt), shows a statistically significant decline following large stock splits, but no significant change following small stock splits. For this measure, the sign test statistic is negative and significant at a level of 1% and we report this in Table 2 by placing the significance stars to the left of the mean adjusted ratio of this measure. The Kruskal-Wallis test indicates that following small and large stock splits, adjusted ratios are statistically different for all four return measures.

Most of the activity measures generate an adjusted ratio distribution that indicates a decline in liquidity (despite a mean ratio which exceeds 1). With a few exceptions, unlike the friction measures, the liquidity changes implied by activity measures do not differ significantly between the small and large stock split groups on the NYSE. The bid and ask depth measures, reported in number of shares, are similar prior to undergoing either small or large stock splits. The mean prices, however, are not similar since the mean price is $42.39 before small stock splits and $65.34 before large stock splits. Following the stock splits, there is no significant statistical difference between the liquidity decline in the small and large stock split groups. In comparison, the bid and ask depth as measured in dollars decreases more (on a percentage basis) following small stock splits but again, there is no significant statistical difference between the two groups. These results seem to contradict the suggestion by Elgers and Murray (1985) that small stock splits are liquidity driven, at least in terms of activity measures of liquidity.

The unadjusted volume measures show an increase following stock splits, giving an appearance of increased liquidity. However, in adjusted terms, all ratios show a decline and are statistically significant. The number of transactions increases slightly when the raw means are examined, although the adjusted ratios indicate a statistically significant decline.

The size measures for stocks on the NYSE also show liquidity declines following stock splits with two exceptions. Capitalization (MarketCap) significantly increases following large stock splits, but this is arguably not economically significant.

In sum, liquidity for NYSE listed stocks declines for almost all measures, whereas a naïve examination that does not account for the change in number of shares and price would indicate an increase in some volume measures following stock splits. The decrease in liquidity is more pronounced following stock splits in friction measures especially bid-ask spread measures and return measures. This liquidity decline is more severe following large stock splits. For activity measures, almost all measures indicate a decline in liquidity, but there are only a few significant differences between the large and small stock splits.

B. Amex One-Day Window Estimation Period

Table 3 reports liquidity measures on the Amex over a one-day estimation window with the caveat that the sample size from this exchange is small. The bid-ask spread measures on the Amex all exhibit a decrease in liquidity, similar to the NYSE. In relative terms, the increase in percentage spreads may appear to be lower on the Amex, however, the spread widths on Amex are about 50% larger than on the NYSE. For example, the percentage spread on Amex is approximately 1% before and 1.6% following the stock splits, while the NYSE percentage bid-ask spreads were 0.4-0.6% before and 0.6-0.8% following the stock splits. Interestingly, there is no difference in adjusted ratios between the small and large stock splits on Amex, whereas the increase was more evident following large stock splits on the NYSE.

The remaining friction measures show a decline in liquidity similar to NYSE, but once again there are minimal statistical differences between small and large stock splits on the Amex. One exeption, the price measure, is significantly different between small and large stock splits with a sharper decline in liquidity for the large splits. The Marsh ratio also shows statistically significant differences between small and large stock splits on Amex, however, the level of significance is 5%. The smaller number of Amex stock splits in our sample could explain this difference between the exchanges, however, the non-parametric tests adjust for sample size.

For activity measures, the absolute values of the depth measures are generally much lower onthe Amex compared to the NYSE. The decline following stock splits is comparable for small stock splits, but the decline is much more pronounced following large stock splits on the Amex. The ask depth on the NYSE was 36 before and 59 following large stock splits, while on the Amex, the ask depth changed from 14 to 17 following large stock splits. The Amex change appears to be more consistent with small stock splits on both the Amex or the NYSE.

For volume measures on the Amex the values are also much smaller compared to the NYSE. Following large stock splits, the number of transactions (NumberTrans) declines significantly, however, the other volume measures only decline marginally. For small stock splits, there are no significant changes following the stock splits.

Size measures reveal mixed changes in liquidity on the Amex. Like the NYSE, the average transaction size increases following large stock splits, but in contrast to the NYSE, the average transaction size falls following small stock splits. Furthermore, the dollar value of the average transaction falls even more dramatically on the Amex compared to the NYSE, possibly reflecting the lower share price for the Amex stocks. The first and last transactions of the day are all much smaller following stock splits. This finding is similar to NYSE, with the exception that the size of the first transaction (Fsize) on the NYSE is unchanged following small stock splits.

In summary, the Amex liquidity changes mirror NYSE liquidity changes except that the absolute levels of the Amex measures tend to be higher than the NYSE equivalents so that any changes following stock splits are less perceptible. For example, the size of the bid-ask spread measures is much larger for stocks on Amex and the depth and volume measures are much smaller. Interestingly, in contrast to the NYSE, there is no difference in bid-ask spread adjusted ratios for small and large stock splits on the Amex. The depth measures exhibit a much larger decline following large stock splits, while there were only minimal changes in volume following both sizes of stock splits. For small stock splits, the average transaction size declined, again in contrast to the NYSE.

C. Nasdaq One-Day Estimation Period

Estimates of liquidity on Nasdaq are reported in Table 4 using a one-day estimation period before and after stock splits. Bid-ask spread adjusted ratios on Nasdaq are comparable to those on the NYSE, however, estimates for Nasdaq bid-ask spread measures are approximately 4 times larger than the NYSE estimates. In contrast with the NYSE and the Amex, the log value of the quoted slope (LQuoteSlope) is significantly smaller following both types of stock splits on Nasdaq. On the NYSE and the Amex neither measure was significantly different across large and small stock splits.

Price measures are similar to the NYSE and the Amex, except that the range of the midpoint of the bid-ask spread (HiLoMdpt) is much larger following stock splits on Nasdaq increasing from $1.08 to $1.85 for small splits and $2.12 to $2.73 for large splits. Return measures that use the quoted bid-ask spread are also much larger for Nasdaq both in value and in the adjusted ratio. Differences between small and large stock splits on Nasdaq are statistically significant for almost all friction measures, mirroring the results for the NYSE.

Depth measures on Nasdaq are much lower than those on the NYSE following stock splits, in fact they are similar to the declines observed on the Amex. Unlike the Amex, the decline in all Nasdaq depth measures is much more pronounced for large stock splits than for small stock splits. The typical Nasdaq market structure and quotation system is the most likely cause for this result.

The estimates for the Nasdaq volume measures are difficult to compare to those for the NYSE and for the Amex since the volume statistics on Nasdaq reflect each direction of the trade as a separate transaction while the specialist exchanges may report trades as two or a single transaction depending on whether the specialist acted as the other party to the trade. Similar to the NYSE results, there is no difference between the liquidity changes for small and large stock splits, except for the number of transactions (NumberTrans) and volume divided by return (VolReturn). Size measures generally exhibit a decline following stock splits on Nasdaq with the exception of the market capitalization (MarketCap). As on NYSE, this finding appears to be statistically significant yet economically meaningless.

In summary, the Nasdaq estimates show a decline in liquidity similar to that of the NYSE. Specifically, the bid-ask spread adjusted ratios are comparable to those at the NYSE, with the same ratio differences between small and large stock splits. Nasdaq, however, has much larger estimated values. Depth ratios are lower and there is a much larger decline evident on Nasdaq following large stock splits, although this may be expected due to the market structure.

D. Longer Interval Liquidity Measure Estimation

In Table 5 we repeat the analysis using a 20-day interval before and after the stock splits. We report the adjusted ratios for each exchange and each size of stock split. The results are generally identical to those in Tables 2-4. Since the one day response may be driving the response in the longer 20 day window, we isolate the immediate response from the 20 day estimation interval by choosing a third non-overlapping sampling interval, which covers a five-day period one week before the stock split and a five-day period one week after the stock split. The results using this sampling interval are reported in Table 6.

We find little evidence of a difference in short and long term liquidity response to stock splits on NYSE . The 20 day estimation period results indicate similar significant liquidity declines as for the 5 day estimation period. The significant differences between large and small stock splits are also identical for the different estimation periods. Hence, the significant decline in liquidity is immediate and persistent for NYSE stock splits.

For the Amex, on the other hand, there do seem to be differences between short-term and long-term response to stock splits. These differences are most apparent in the activity measures. The general insignificance of the five day results suggest that the liquidity decline in activity is a short-term phenomenon on the Amex. The same applies to significant differences between large and small stock splits on the Amex. These differences disappear after an initial short-term effect.

On Nasdaq, the short term and long term liquidity response to stock splits is similar, with only some minor reduction in the number of measures that are significantly different from 1 in the longer term response. This suggests that the decline in liquidity is pervasive and sustained for

this exchange, just as it is for the NYSE. Two exceptions are the daily volume (DailyVolume) and daily volume as measured in dollars ($DailyVolume). These measures indicate that for small stock splits the average transaction size in dollars may have temporarily increased before or declined after stock splits, but if the week before and after the stock splits is excluded, there is no significant difference between them. This provides some evidence that at least for small stock splits on Nasdaq, liquidity is not affected as measured by the average transaction dollar value.

From our analysis of different sampling periods (1-day, 20-day, and non-overlapping 5-day) around the stock split we find that for most activity variables there seems to be a clear shift in the mean adjusted ratio when moving from immediate to longer-term response (even if this does not lead to significance in the Kruskal-Wallis tests). For example, using a 1-day window, unadjusted volume on Amex approximately doubles for stocks that undergo a large stock split, well exceeding the expected volume if no other trading characteristics change due to the stock split. When estimates from the 20-day estimation period are examined, a significant decline in volume is apparent. No such decline appears in the 5-day estimation period. For stocks that trade on the NYSE and Nasdaq, the volume adjustment is rather different from the Amex. The 1-day window shows a marked decline in the volume for stocks on the NYSE following a stock split, but the 5-day estimation period away from the stock splits indicates minimal differences in adjusted volume following small stock splits. This pattern suggests that volume on the day before the split may be 'abnormal' on NYSE and this could be causing the 1-day decline in liquidity. A few days later, a reversal occurs and volume quickly returns to the adjusted post-split level.

To better examine the short and longer term liquidity response, daily plots showing the distribution of the liquidity measures have been generated. Figure 2 shows the distribution of stock prices for stocks that underwent large, respectively small stock splits on each of the 10 days before and after a stock split in a Box-and-Whisker diagram[13]. For each of the exchanges and for each stock split magnitude, the immediate change is as expected and the distribution of the stock price in subsequent days seems stable. The two horizontal lines across each figure indicate the raw mean of the daily raw mean prices (unadjusted for the split) for the ten days

[13] The two lines on the exterior of the box represent the 25th and 75th percentiles and the box itself is the interquartile range (IQR). The line in the interior of the box is the 50th percentile (median) and the lines (whiskers) extend out rom the box 1.5 times the IQR, with any observations outside these whiskers represented by a circle.

before, respectively for the ten days after the stock split. Of course, to establish whether the gap between these lines is commensurate with the expected price change, we need to formally test equivalence of the adjusted means. Although not reported in the tables, we therefore examine the statistical significance of the difference between the adjusted means. We find that for all exchanges there is a statistically significant difference in mean price level between the adjusted means for stocks that underwent a large stock split (10% statistical significance for stocks on NYSE and Amex, 5% statistical significance for stocks on Nasdaq). For stocks that underwent a small stock split, only Nasdaq stocks have a statistically significant difference (at a 1% level) in mean price level.

Figure 3 shows the distribution of the log ask depth for stocks that underwent large, respectively small stock splits. Again, the two horizontal lines indicate the raw mean of the daily raw mean log ask depth (unadjusted for the split) for the ten days before, respectively for the ten days after the stock split. Based on these raw means, stocks on Amex and NYSE show a decline for both large-split and small-split stocks. For Nasdaq, however, no such evidence exists. The mean of log ask depth remains virtually identical after both large and small stock splits. Interestingly, the Nasdaq distributions are much more positively skewed than the NYSE and/or Amex distributions. This skewness seems to increase after large stock splits on Nasdaq. This increasing skew explains why we still find significant liquidity declines based on the ask depth activity measure for Nasdaq. In fact the decline on Nasdaq is stronger than on the other exchanges..

When a 20-day window is examined, stocks on the NYSE and the Amex also exhibit a significant decline in the adjusted ask depth. For stocks on the NYSE the decline is larger for the small-split stocks, with the reverse true for Amex stocks. When we focus on the 5-day window, stocks on the NYSE show little difference before and after the stock split in adjusted ask depth.

E. A Signaling Effect

Copeland's (1988) signaling model implies a positive relationship between stock splits and (abnormal) returns. Since some of the liquidity measures involve returns on the stocks, it seems worthwhile to investigate the impact of signaling on the liquidity measures. Table 7 reports regression results where the dependent variable is the liquidity measure and the explanatory

variable is the cumulative abnormal return (CAR). The CAR is computed as the two-day cumulative announcement return (day−1,0) appropriately adjusted by the stock's beta (which is computed over the 40 days prior to the announcement). To control for split size, and exchange, we included dummy variables for large stock splits (SSLarge =1) and Amex (EXAmex =1), respectively Nasdaq (EXNasdaq =1) stock splits. The F-tests for each of these regressions generally indicates significant explanatory variables. On closer inspection, most of this significance comes from the split size dummy and the Nasdaq dummy. Whereas the split size dummy is significant for both friction and activity regressions, the Nasdaq dummy is predominantly significant for the activity measures. There is very little evidence for significance in the CAR variable.

F. Structural Changes in 1997

The change in order handling rules and decrease in the minimum tick size from one-eighth to one-sixteenth suggests that there may be a structural change in our data in 1997. To examine the effects of these changes we estimate the liquidity effects of stock splits that occur in 1996 and 1998 and compare the findings. Even though the minimum tick size impacted all exchanges, we include only the NYSE and Nasdaq in our examination since the number of stock splits in 1996 and 1998 is limited on the Amex. We examine only large stock splits and our sample size on the NYSE is 64 stock splits in 1996 and 144 stock splits in 1998. Nasdaq had 171 large stock splits in 1996 and 198 in 1998. We exclude the year 1997 since the changes occurred that year, and it could be argued that the changes may not have had an immediate effect.

On the NYSE, there are two clear patterns that emerge from comparing liquidity measures in 1996 with those measures in 1998. Adjusted ratios show that bid-ask spread measures denominated in dollars (dollar spread ($Spread) and effective dollar spread (Eff$Spread)) both show significant differences between the two years. One explanation for this phenomenon may be a decline in average price, however, the mean price for this sample of stocks increases from $65.03 in 1996 to $68.79 in 1998. The percentage bid ask spreads (percentage bid -ask spread (%Spread) and effective bid-ask spread (Eff%Spread)) are not significantly different.

On the Nasdaq, the adjusted friction measures show differences between 1996 and 1998. This is

similar to the NYSE, but the pattern is even stronger and is present in the percentage spreads on Nasdaq. There is also an increase in depth, on Nasdaq. While it is difficult to compare two very different market structures, differences between the NYSE and Nasdaq are less apparent in 1998, suggesting the structural changes may be increasing competition and thereby forcing the exchanges to be more similar.

We further examine the liquidity measure distributions in the two years around the potential structural change by creating box and whisker plots in Figure 4 for the log effective spread on Nasdaq and the NYSE in 1996 and in 1998, respectively. On Nasdaq, the log effective spread resembles a normal distribution in 1998 as compared to a much more positively skewed, long-tailed distribution in 1996. This would suggest fewer large 'outliers' among the effective spreads for stocks that split after 1997. Figure 4 also confirms the downward drift in the medians of the log effective spread with the drift appearing to be stronger in 1998. Contrary to Nasdaq, on the NYSE the log effective spread appears to resemble a normal distribution in 1996 compared to a much more positively skewed, long-tailed distribution in 1998. This would suggest many more large 'outliers' among the effective spreads for stocks that split after 1997. The downward drift in the medians of the log effective spread appears to be stronger in 1998.

Table 8 shows that there appears to be a clear structural change evident on Nasdaq, with significant differences in the bid-ask spread friction measures and depth activity measures before and after 1997. On the NYSE, there are only a few significant differences between the 1996 and 1998 stock split liquidity changes. Since we are only using a subset of the population of stocks any conclusions are restricted to the sample of stocks that incurred a stock split. With that caveat, it appears that the change in order handling rules has had a larger impact on liquidity than the decrease in the minimum tick size. Our results indicate that the addition of liquidity providers through the change in order handling rules on Nasdaq may serve to reduce the disparity in percentage spreads and depths noted in the earlier comparisons across exchanges.

3. Conclusion

This research examines the impact of stock splits on 31 liquidity measures, broadly classified as either friction measures or activity measures and more finely classified as bid-ask spread, price and return measures in the friction measure category and depth, volume and size measures in the activity measure category. Overall, we find a pervasive decline in liquidity on all three major U.S. exchanges when adjusted measures are used to calculate the impact on liquidity. In contrast, many of the activity measures increase (and friction measures decrease) following stock splits if no adjustment is made for the change in the number of outstanding shares and share price. This naïve perception may be one of the motivators of stock splits.

We find that there are some differences between measures across exchanges and between small and large stock splits. For stock splits on the NYSE, the liquidity decline is more severe for friction measures, especially bid-ask spread measures. Stocks on the Amex have similar liquidity measure changes, but the scale of the measures is much higher than those on the NYSE. Following stock splits on Nasdaq, the friction measure declines mirror the friction measure declines on the NYSE, but there is also a large reduction in liquidity shown by declines in depth measures. The liquidity changes are different for small and large stock splits, with the differences much more pronounced on the NYSE and Nasdaq compared to the Amex. Large stock splits exhibit more severe declines in liquidity, but when we examine the longer-term liquidity changes and the liquidity changes excluding the period immediately surrounding the stock split, some of the differences between small and large stock splits diminish. Volume measures are also suspect, since our analysis shows that in the period immediately around the stock split there may be unusual activity that is not sustained over the long term. In addition, the structural changes that occurred in 1997 also had an impact on the liquidity changes following stock splits. The change in order handling rules appears to have had a much larger impact on Nasdaq than the simultaneous reduction in minimum tick size.

Our comprehensive analysis of liquidity encompasses a 6-year period and in that time our analysis is subject to changing market characteristics such as increased competition, reduced risk aversion or even an increase in the number of noise traders due to the extended length of the bull market and the advent of on-line trading. Despite a concern that during the 6 years the trading

environment may have changed, this long period of study allows a thorough assessment of liquidity changes across specific liquidity measures. Besides more evidence that liquidity is reduced following stock splits, our results can also be used to choose a liquidity proxy. Our identification of different classifications of liquidity proxies and their different responses to stock splits should alert careful researchers that controlling liquidity without impacting on other trading characteristics is not easy. Our study is one step in further understanding the complete picture of liquidity changes following stock splits. Future work in examining liquidity changes vis-à-vis stocks moving exchanges and across different stock characteristics and events can continue this pursuit.

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Table 1 Liquidity Proxies The names used to describe liquidity proxies in the literature are identified along with the variable name used in subsequent tables, calculation details and notable studies that have used this proxy. In illustrating calculation details the following abbreviations are used: Q_A is the ask depth, Q_B is the bid depth, P_A is the ask price, P_B is the bid price, P_T is the trade price at time T, P_{T-1} is the previous trade price, PM_T is the midpoint of the bid and ask price outstanding at time T.

Liquidity Proxy	**Variable**	**Calculation**	**Studies**
FRICTION MEASURES			
Bid-Ask Spread Measures			
Quoted Bid-Ask Spread, or Dollar Spread	\$Spread	$P_A - P_B$	Amihud and Mendelson (1986)
Percentage Quoted Bid-Ask Spread, or Relative Spread	%Spread	$(P_A - P_B) / P_M$	Copeland (1979)
Effective Bid-Ask Spread, Realized Bid-Ask Spread	Eff\$Spread	$2 \mid P_T - P_M \mid$	Hasbrouck and Schwartz (1988)
Effective Percentage Bid-Ask Spread, Realized Percentage Bid-Ask Spread	Eff%Spread	$2 \mid P_T - P_M \mid / P_M$	Hasbrouck and Schwartz (1988)
Log Spread	LogSpread	Log (Ask/Bid)	Hasbrouck and Seppi (2000)
Quote Slope (1,000)	QuoteSlope	$(P_A - P_B) / (\text{Log } (Q_A) + \text{Log } (Q_B))$	Hasbrouck and Seppi (2000)
Log Quote Slope	LQuoteSlope	$\text{Log } (P_A - P_B) / (\text{Log } (Q_A) + \text{Log } (Q_B))$	Hasbrouck and Seppi (2000)
Price Measures			
Price	Price	First price during the day	Haugen (1999)
HILO	HiLo	Difference between the high and low price during the day	
HILO - midpoint	HiLoMdpt	Difference between the high and low midpoint of the bid-ask spread during the day	
Return Measures			
Marsh (1,000)	Marsh	Absolute value of intraday trade to trade return divided by number of transactions	Marsh and Rock (1986)
Intraday Absolute Return Per Quote Midpoint (X1,000)	IntraQRet	Absolute value of the return derived from quote midpoints	

Intraday Standard Deviation (X1,000)	IntraSD	Standard deviation of the intraday transaction return	Bessembinder and Kaufman (1997), Piwowar (1997)
Intraday Standard Deviation	IntraSDMdpt	Standard deviation of the return derived from quote midpoints	
Activity Measures			
Depth Measures			
Ask Depth	AskDepth	Q_A	Lee, Mucklow and Ready (1993)
Bid Depth	BidDepth	Q_B	Lee, Mucklow and Ready (1993)
Log Depth	LogDepth	Log (Q_A) + Log (Q_B)	Hasbrouck and Seppi (2000)
Dollar Ask Depth	$AskDepth	$Q_A * P_A$	
Dollar Bid Depth	$BidDepth	$Q_B * P_B$	
Depth/Spread (1,000)	Depth/Spread	$(Q_B + Q_A)/ (P_A - P_B)$	Moulton (1998)
Volume Measures			
Daily Volume (1,000)	DailyVolume	Number of shares traded	Copeland (1979), Lamoureux and Poon (1987), Conroy, Harris and Benet (1990)
Daily Dollar Volume (1,000)	$DailyVolume	Daily dollar value of transactions	
Number of Transactions	NumberTrans	Number of transactions	Edmister and James (1983), Jones, Kaul and Lipson (1994), Muscarella and Vetsuypens (1996)
Volume/Return (1,000)	VolReturn	Number of shares traded per unit of return	Marsh and Rock (1986)
Size Measures			
Market Capitalization (1,000,000)	MarketCap	Price times number of shares outstanding	Haugen (1999)
Turnover Rate	TurnoverRate	Number of shares traded as fraction of the number of shares outstanding	Datar, Naik and Radcliffe (1998)
Average Transaction Size	Transaction	Average number of shares per transaction	
Average Transaction Size in Dollars (1,000)	$Transaction	Average dollar value of each transaction	
Percentage of Trading Inside the Bid-Ask Spread	%InsideSprd	Percentage of transactions that occur within the bid-ask spread	
First Trade Size	FSize	Number of shares in the opening transaction	
Last Trade Size	LSize	Number of shares in the final day's transaction	

Table 2 New York Stock Exchange One-Day Liquidity Estimates. Estimates of the liquidity measures detailed in Table 1 are reported separately for small (three for two) and large (two for one) splits for the day before and the day after a stock split on the New York Stock Exchange during the period March 1993 - December 1998. The raw means across stocks are reported both before and after stock splits and an adjusted unit ratio is calculated for each measure. This is a ratio of the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test. If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for different split sizes are tested for equality using the Kruskal-Wallis test.

	BEFORE		AFTER		ADJUSTED RATIO	
	3:2	2:1	3:2	2:1	3:2	2:1
Friction Measures						
Bid-Ask Spread Measures						
$Spread	$0.20	$0.21	$0.19	$0.18	1.47***	1.85*** +++
%Spread	0.6%	0.4%	0.8%	0.6%	1.41***	1.71*** +++
Eff$Spread	$0.16	$0.16	$0.16	$0.15	1.53***	1.85*** +++
Eff%Spread	0.4%	0.3%	0.6%	0.5%	1.50***	1.78*** +++
LogSpread	5.7	3.8	7.8	6.2	1.41***	1.71*** +++
QuoteSlope	0.51	0.54	0.46	0.39	1.72***	2.08*** +++
LquoteSlope	2.32	2.29	2.16	1.90	1.07*	1.01++
Price Measures						
Price	$42.39	$65.34	$29.41	$35.31	1.06***	1.13**
HiLo	$0.94	$1.52	$0.94	$1.22	2.09***	2.10***
HiLoMdpt	$1.40	$1.61	$1.01	$1.32	2.18***	2.35***
Return Measures						
Marsh	0.08	0.03	0.10	0.05	1.58***	1.56*** ++
IntraQRet	1.15	0.70	1.53	1.13	1.59***	1.78*** +++
IntraSD	2.20	1.46	3.26	2.52	2.84***	1.73*** +++
IntraSDMdpt	2.67	2.69	2.37	2.05	1.25	*** 0.99 +++
Activity Measures						
Depth Measures						
AskDepth	36	36	41	59	***1.17	***1.01
$AskDepth	1,485	2,293	1,182	2,172	***1.22	***1.09
BidDepth	22	23	27	41	***1.18	***0.96
$BidDepth	929	1,489	770	1,486	***1.22	***1.05
LogDepth	5.10	5.20	5.34	6.03	***0.91	***0.90
Depth/Spread	4.44	4.29	5.34	7.69	***0.88	***0.55 +++
Volume Measures						
DailyVolume	222	490	300	673	***1.24	***0.99
$DailyVolume	$11,089	$37,191	$11,673	$34,208	***1.29	***1.07
NumberTrans	128	269	142	300	***0.91	***0.65 +++
VolReturn	18,571	51,233	15,516	45,749	***1.45	***1.18 ++
Size Measures						
MarketCap	4,454	9,702	4,391	9,737	1.00	1.00***
TurnoverRate	0.31%	0.51%	0.29%	0.42%	***1.34	***1.07
Transaction	1,342	1,317	1,447	1,667	***0.82	***0.73 +++
$Transaction	$54	$86	$41	$62	***0.86	***0.80
%InsideSprd	38.2%	38.2%	36.6%	35.6%	***1.15	***1.02
Fsize	10,665	18,992	11,879	26,261	3.78	***1.91 +++
Lsize	8,142	10,817	6,249	12,833	***2.60	***2.89

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+ small and large stock split adjusted means significantly different at a level of 10%, ++ small and large stock split adjusted means significantly different at a level of 5%, +++ small and large stock split adjusted means significantly different at a level of 1%

Table 3 American Stock Exchange One-Day Liquidity Estimates Estimates of the liquidity measures detailed in Table 1 are reported separately for small (three for two) and large (two for one) splits for theday before and the day after a stock split on the American Stock Exchange during the period March 1993 - December 1998. The raw means across stocks are reported both before and after stock splits and an adjusted unit ratio is calculated for each measure.This is a ratio of the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test. If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for different split sizes are tested for equality using the Kruskal-Wallis test.

	BEFORE		AFTER		ADJUSTED RATIO	
	3:2	2:1	3:2	2:1	3:2	2:1
Friction Measures						
Bid-Ask Spread Measures						
$Spread	$0.32	$0.36	$0.29	$0.29	1.42***	1.68*** +++
%Spread	1.2%	1.1%	1.6%	1.6%	1.40***	1.57*** +
Eff$Spread	$0.24	$0.29	$0.23	$0.23	1.53***	1.71*** ++
Eff%Spread	0.9%	0.8%	1.3%	1.2%	1.53***	1.62***
LogSpread	12.1	10.7	15.9	15.8	1.40***	1.57*** +++
QuoteSlope	1.33	1.56	1.06	1.12	1.91***	6.18***
LquoteSlope	3.86	4.23	3.49	3.61	1.14**	2.47
Price Measures						
Price	$29.38	$42.17	$20.06	$22.38	1.04***	1.12** ++
HiLo	$0.70	$1.14	$0.76	$1.06	1.90***	2.14***
HiLoMdpt	$0.80	$1.14	$0.80	$1.38	2.76***	2.50***
Return Measures						
Marsh	0.81	0.42	0.56	0.91	1.46	1.55 ++
IntraQRet	5.74	1.89	2.81	2.91	1.95***	1.54***
IntraSD	4.87	4.39	6.75	6.48	1.60***	11.49***
IntraSDMdpt	4.47	5.06	4.13	4.55	1.29	*** 0.90 +++
Activity Measures						
Depth Measures						
AskDepth	13	14	15	17	*** 1.37	*** 0.88
$AskDepth	403	510	300	354	*** 1.44	** 0.96
BidDepth	10	9	9	11	*** 0.88	*** 0.83
$BidDepth	278	324	179	229	*** 0.88	*** 0.91
LogDepth	3.55	3.16	3.59	3.75	*** 0.82	*** 0.73
Depth/Spread	1.18	1.15	1.28	1.77	*** 0.96	*** 0.51 ++
Volume Measures						
DailyVolume	23	25	32	53	1.57	** 1.28
$DailyVolume	$782	$1,310	$896	$1,642	1.62	1.36
NumberTrans	21	34	28	61	1.35	*** 0.93 +++
VolReturn	1,351	1,343	1,270	2,081	2.24	*** 1.00 ++
Size Measures						
MarketCap	409	535	355	534	1.00***	1.00**
TurnoverRate	0.22%	0.39%	0.26%	0.47%	1.68	1.43
Transaction	838	639	680	746	*** 0.77	*** 0.71
$Transaction	$24	$27	$14	$15	*** 0.80	*** 0.77
%InsideSprd	32.1%	30.1%	31.3%	33.7%	1.12	1.13
Fsize	2,128	1,163	1,555	1,766	*** 2.16	* 1.45
Lsize	1,266	823	824	929	*** 1.56	*** 1.30

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+ small and large stock split adjusted means significantly different at a level of 10%, ++ small and large stock split adjusted means significantly different at a level of 5%, +++ small and large stock split adjusted means significantly different at a level of 1%

Table 4 Nasdaq Stock Exchange One-Day Estimates Estimates of the liquidity measures detailed in Table 1 are reported separately for small (three for two) and large (two for one) splits for the day before and the day after a stock split on the Nasdaq Stock Exchange during the period March 1993 - December 1998. The raw means across stocks are reported both before and after stock splits and an adjusted unit ratio is calculated for each measure. This is a ratio of the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test. If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for different split sizes are tested for equality using the Kruskal-Wallis test.

	BEFORE		AFTER		ADJUSTED RATIO	
	3:2	2:1	3:2	2:1	3:2	2:1
Friction Measures						
Bid-Ask Spread Measures						
$Spread	$0.78	$0.86	$0.76	$0.69	1.60***	1.82*** +++
%Spread	2.9%	2.5%	4.1%	3.7%	1.55***	1.67*** +++
Eff$Spread	$0.60	$0.65	$0.59	$0.53	1.61***	1.84*** +++
Eff%Spread	2.2%	1.8%	3.1%	2.8%	1.57***	1.74*** +++
LogSpread	2.87	2.47	4.09	3.75	1.55***	1.67*** +++
QuoteSlope	2.33	2.73	2.29	2.15	2.02***	2.62*** +++
LquoteSlope	2.96	3.17	2.97	3.05	1.13***	1.21*** +++
Price Measures						
Price	$33.67	$49.36	$23.15	$27.68	1.05***	1.14***
HiLo	$1.41	$2.47	$1.37	$2.03	1.97***	2.17*** +++
HiLoMdpt	$1.08	$2.12	$1.85	$2.73	5.94***	4.76*** +
Return Measures						
Marsh	0.98	0.80	1.43	0.85	2.08	1.72**
IntraQRet	3.31	3.89	10.31	9.12	3.40***	2.79*** +++
IntraSD	10.75	8.77	16.37	14.34	1.73***	1.81*** +++
IntraSDMdpt	5.32	6.03	10.09	10.59	*2.00	*** 1.51 +++
Activity Measures						
Depth Measures						
AskDepth	9	8	10	9	***0.77	***0.57 +++
$AskDepth	302	428	237	260	***0.81	***0.66 +++
BidDepth	9	8	10	9	***0.82	***0.57 +++
$BidDepth	287	405	237	238	***0.85	***0.64 +++
LogDepth	3.97	3.76	3.98	3.85	***0.80	***0.62 +++
Depth/Spread	0.47	0.57	0.56	0.70	***0.57	***0.37 +++
Volume Measures						
DailyVolume	187	741	217	917	***2.53	***1.86 +
$DailyVolume	$9,088	$56,143	$7,614	$49,078	**2.60	***2.03
NumberTrans	167	1,051	187	1,161	***1.27	***1.02 +++
VolReturn	10,057	38,958	19,074	21,927	***3.00	***2.34 +++
Size Measures						
MarketCap	933	2,419	930	2,355	1.02***	1.02***
TurnoverRate	0.83%	2.65%	0.78%	2.46%	**2.57	***2.02
Transaction	1,075	1,004	1,042	1,097	***0.94	***0.71 +++
$Transaction	$37	$48	$24	$28	***0.98	***0.80 +++
%InsideSprd	32.6%	31.5%	31.0%	30.0%	***0.98	***1.00
Fsize	609	592	627	597	***2.20	***1.35 +++
Lsize	1,438	1,409	1,300	2,115	***2.33	***3.11

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+ small and large stock split adjusted means significantly different at a level of 10%, ++ small and large stock split adjusted means significantly different at a level of 5%, +++ small and large stock split adjusted means significantly different at a level of 1%

Table 5 Adjusted Ratios Using A Twenty-Day Estimation Period Adjusted ratios for liquidity measures detailed in Table 1 are reported separately for small (three for two) and large (two for one) splits for the twenty days before and after a stock split on the NYSE, the Amex and the Nasdaq Stock Exchange during the period March 1993 - December 1998. The adjusted ratio is calculated as the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test. If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for different split sizes are tested for equality using the Kruskal-Wallis test.

	NYSE		Amex		Nasdaq	
	Small	Large	Small	Large	Small	Large
Friction Measures						
Bid-Ask Spread Measures						
$Spread	1.38***	1.67***+++	1.35***	1.64***+++	1.36***	1.53***+++
%Spread	1.36***	1.64***+++	1.30***	1.59***+++	1.32***	1.46***+++
Eff$Spread	1.41***	1.73***+++	1.43***	1.66***+++	1.37***	1.56***+++
Eff%Spread	1.38***	1.70***+++	1.40***	1.60***+++	1.33***	1.50***+++
LogSpread	1.36***	1.64***+++	1.30***	1.59***+++	1.32***	1.46***+++
QuoteSlope	1.49***	1.72***+++	1.61***	2.60***+++	1.71***	2.22***+++
LquoteSlope	0.99	***0.94+++	0.93	1.08	1.11***	1.14***+++
Price Measures						
Price	1.03***	1.02***	1.04*	1.05	1.04***	1.05***+
HiLo	1.46***	1.58***+++	1.51***	1.98***+	1.50***	1.67***+++
HiLoMdpt	1.49***	1.68***+++	1.51***	2.13***++	1.83***	1.98***+++
Return Measures						
Marsh	1.27***	1.45***+++	1.29**	1.69**++	1.43***	1.47***
IntraQRet	1.34***	1.55***+++	1.21***	1.46***+++	2.05***	2.30***+++
IntraSD	1.40***	1.69***+++	1.36***	1.67***+++	1.40***	1.52***+++
IntraSDMdpt	***0.88	***0.73+++	***0.89	***0.83++	***1.06	***0.92+++
Activity Measures						
Depth Measures						
AskDepth	***0.98	***0.94	**1.09	***0.92++	***0.75	***0.58+++
$AskDepth	***1.01	***0.96	*1.14	*0.98++	***0.78	***0.62+++
BidDepth	***0.96	***0.98+	**0.94	***0.85	***0.74	***0.58+++
$BidDepth	***0.97	***1.00+	0.97	***0.89	***0.76	***0.61+++
LogDepth	***0.94	***0.93	***0.90	***0.72+++	***0.80	***0.64+++
Depth/Spread	***0.73	***0.58+++	***0.76	***0.54+++	***0.60	***0.43+++
Volume Measures						
DailyVolume	***1.03	***0.98	0.99	***0.09++	***1.10	***0.99++
$DailyVolume	**1.07	***1.01	1.06	***1.00+	***1.15	***1.06+
NumberTrans	***0.80	***0.62+++	***0.79	***0.67+++	***0.86	***0.72+++
VolReturn	***0.87	***0.78+++	***0.82	***0.55+++	***1.00	***0.94+++
Size Measures						
MarketCap	0.96**	0.99***	1.01	1.00	1.02***	0.98***+
TurnoverRate	***1.10	***1.09	1.07	**1.04	***1.15	***1.18
Transaction	***0.85	***0.77+++	***0.84	***0.68+++	***0.84	***0.69+++
$Transaction	***0.87	***0.79+++	***0.87	***0.71+++	***0.86	***0.72+++
%InsideSprd	***0.95	***0.90+++	**0.98	***0.95	1.05	**1.05
Fsize	1.27	**1.33	**1.02	***0.75+++	***0.91	***0.73+++
Lsize	*1.13	***1.04	**0.95	***0.83	***0.99	***0.89+++

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+ small and large stock split adjusted means significantly different at a level of 10%, ++ small and large stock split adjusted means significantly different at a level of 5%, +++ small and large stock split adjusted means significantly different at level of 1%

Table 6 Adjusted Ratios Using A Five-Day Estimation Period Excluding The Week Before and After Stock Splits
Adjusted ratios for liquidity measures detailed in Table 1 are reported separately for small (three for two) and large (two for one) splits for the five days before and after a stock split (excluding the week before and after the stock splits) on the NYSE, the Amex and the Nasdaq Stock Exchange during the period March 1993 - December 1998. The adjusted ratio is calculated as the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test. If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for different split sizes are tested for equality using the Kruskal-Wallis test.

	NYSE		Amex		Nasdaq	
	Small	Large	Small	Large	Small	Large
Friction Measures						
Bid-Ask Spread Measures						
$Spread	1.39***	1.67***+++	1.35***	1.61***+++	1.38***	1.54***+++
%Spread	1.37***	1.66***+++	1.31***	1.57***+++	1.34***	1.49***+++
Eff$Spread	1.42***	1.74***+++	1.46***	1.65***+++	1.41***	1.60***+++
Eff%Spread	1.40***	1.72***+++	1.42***	1.62***++	1.38***	1.55***+++
LogSpread	1.37***	1.66***+++	1.31***	1.57***+++	1.34***	1.49***+++
QuoteSlope	1.55***	1.75***+++	1.75***	16.91***+++	1.75***	2.31***+++
LquoteSlope	1.02	***0.94+++	1.00	4.98	1.11***	1.11***+++
Price Measures						
Price	1.02**	1.02***	1.04**	1.03	1.03***	1.04***
HiLo	1.60***	1.75***+++	1.84***	2.23***	1.76***	1.76***++
HiLoMdpt	1.62***	1.72***+++	1.69***	2.98***++	2.18***	2.26***+
Return Measures						
Marsh	1.46***	1.49***+++	1.42	1.49	1.54	1.70**
IntraQRet	1.38***	1.60***+++	1.19***	1.59***+++	1.73***	2.06***+++
IntraSD	1.44***	1.70***+++	1.38***	1.65***++	1.45***	1.64***+++
IntraSDMdpt	***0.93	***0.77+++	***0.87	***0.95	***1.07	***0.88+++
Activity Measures						
Depth Measures						
AskDepth	**1.27	***1.00	1.43	1.32	***0.77	***0.59+++
$AskDepth	1.31	***1.02	1.47	1.37	***0.61	***0.61+++
BidDepth	***1.15	**1.03	0.99	1.05	***0.60	***0.60+++
$BidDepth	*1.16	*1.04	1.04	1.07	***0.62	***0.62+++
LogDepth	***0.98	***0.94	*0.96	***2.16+++	***0.83	***0.56+++
Depth/Spread	***0.95	***0.60+++	***0.90	***0.74++	***0.63	***0.46+++
Volume Measures						
DailyVolume	*1.37	***1.04	1.45	1.32	*1.53	***1.41
$DailyVolume	1.40	***1.05	1.55	1.39	1.61	***1.44
NumberTrans	***0.88	***0.66+++	**1.01	***0.83+	***1.05	***0.87+++
VolReturn	***1.12	***0.82+++	1.17	***0.91+	***1.59	***1.48
Size Measures						
MarketCap	1.00	0.96	1.00	1.01	1.01***	0.97***
TurnoverRate	1.43	1.17	1.55	1.40	1.63	1.65
Transaction	***0.95	***0.79+++	**0.94	***0.81	***0.93	***0.76+++
$Transaction	***0.97	***0.80+++	*0.98	***0.82	***0.96	***0.78+++
%InsideSprd	***0.96	***0.92++	***1.02	0.96	***1.07	**1.12
Fsize	2.28	**1.39	1.52	*1.11	***1.15	***0.99+++
Lsize	1.62	***1.49++	1.67	**1.04	***1.40	***1.30

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+small and large stock split adjusted means significantly different ata level of 10%, ++ small and large stock split adjusted means significantly different at a level of 5%,+++ small and large stock split adjusted means significantly different at a level of 1%.

Table 7 Tests of the Signaling Effect of the Stock Split Announcement Using Regression Analysis
Adjusted liquidity ratios for each firm are used as the dependent variable in the following cross-section regressions to test if there is explanatory power of the announcement effect on the change in liquidity at the stock split. The signaling effect is approximated using various liquidity measures based on the two-day announcement return (Day –1, 0) for all firms that had an announcement within 3 calendar months of the actual stock split. We use the cumulative abnormal return (CAR) calculated using the beta of the firm in the 40 days prior to the announcement. We also control for the different size of the stock split by including a dummy variable (SSLarge) with a value of 1 if the stock split is large. We control for the different stock exchanges by including an American stock exchange dummy (EXAmex) and a Nasdaq dummy (EXNasdaq). We report the F statistic for the overall significance of the regression.

	F-test	SSLarge	EXAmex	EXNasdaq	CAR
Friction Measures					
Bid-Ask Spread Measures					
$Spread	24.87***	0.280***	-0.098	0.037	-0.103
%Spread	12.88***	0.182***	-0.073	0.039	-0.281
Eff$Spread	13.96***	0.252***	-0.072	0.008	-0.388
Eff%Spread	9.76***	0.204***	-0.084	-0.008	-0.498*
LogSpread	9.38***	0.173***	-0.103	0.010	-0.265
QuoteSlope	11.18***	-0.054	0.236	0.454***	0.482
LquoteSlope	6.03***	0.059*	0.097	0.158***	0.178
Price Measures					
Price	14.67***	0.091***	-0.018	0.004	0.073
HiLo	1.79	0.198**	-0.011	-0.061	0.723
HiLoMdpt	5.64***	-0.619	0.343	2.973***	-1.032
Return Measures					
Marsh	6.15***	-0.285	-0.278	0.138	7.797***
IntraQRet	4.01***	-0.464	-0.073	1.275***	1.027
IntraSD	3.58***	0.200	4.493***	-0.333	-2.457
IntraSDMdpt	5.08***	-0.413**	-0.036	0.610***	0.276
Activity Measures					
Depth Measures					
AskDepth	29.13***	-0.206***	-0.163*	-0.442***	0.468
$AskDepth	24.70***	-0.167***	-0.164	-0.445***	0.653*
BidDepth	16.85***	-0.238***	-0.211*	-0.396***	0.313
$BidDepth	15.40***	-0.191***	-0.242*	-0.410***	0.362
LogDepth	28.66***	-0.141***	-0.182***	-0.220***	-0.283
Depth/Spread	15.58***	-0.262***	-0.052	-0.241***	0.398
Volume Measures					
DailyVolume	5.43***	-0.510**	0.154	0.968***	1.566
$DailyVolume	5.25***	-0.434*	0.148	1.031***	1.712
NumberTrans	21.74***	-0.250***	0.356***	0.359***	0.196
VolReturn	2.64**	-0.710	0.287	1.273**	6.493
Size Measures					
MarketCap	4.93***	-0.008**	0.004	0.012***	-0.015
TurnoverRate	5.30***	-0.402	0.141	1.022***	1.694
Transaction	8.17***	-0.160***	-0.058	0.020	-0.032
$Transaction	4.08***	-0.114***	-0.073	0.029	0.056
%InsideSprd	2.19*	0.007	0.098	-0.057*	-0.362
Fsize	1.88	-1.258**	-1.101	-1.069*	-0.625
Lsize	0.81	0.160	-1.279	-0.316	0.148

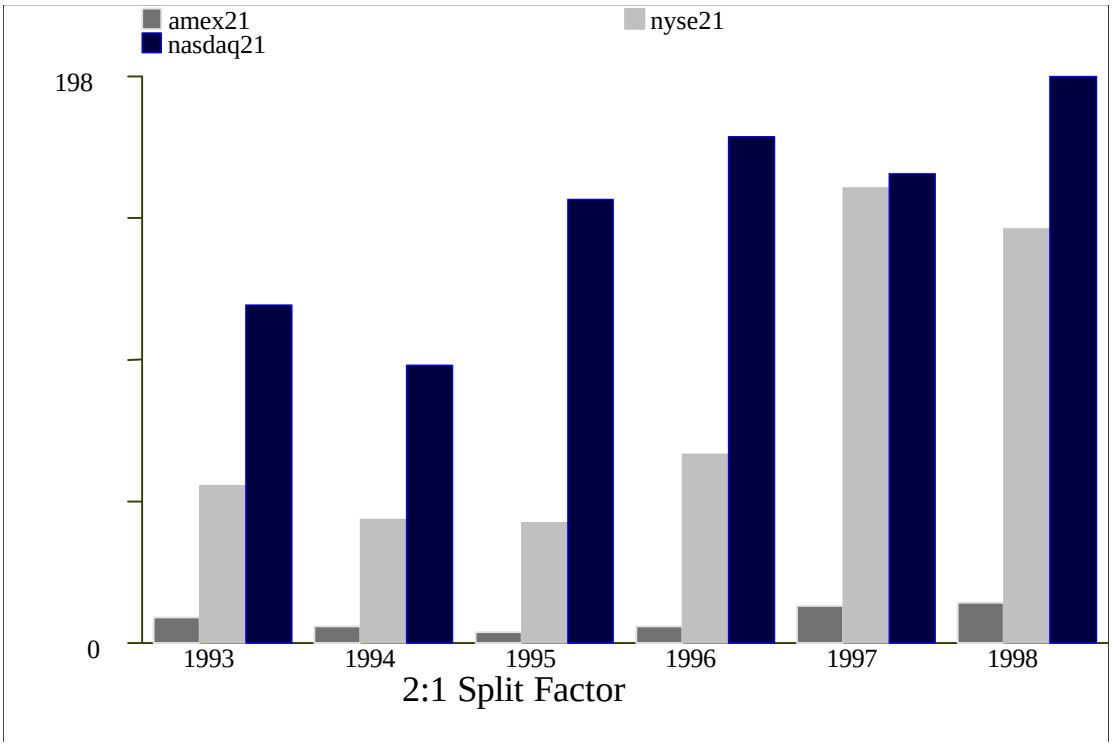
* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.

Table 8 Adjusted Ratios Before and After Structural Changes in 1997 Adjusted ratios for liquidity measures detailed in Table 1 are reported for large (two for one) splits for the ten days before and after a stock split on the NYSE and the Nasdaq Stock Exchange during the period January to December 1996 and January to December 1998. The adjusted ratio is calculated as the measure after the stock split divided by the measure before the stock split but adjusted to what would be expected following the stock split if only the price and number of shares were adjusted and no other trading characteristics were altered. The adjusted ratio is calculated for each stock, and the mean is reported across stocks. The adjusted ratio is compared to the value of 1 and the statistical difference is determined using the sign test If the estimate is smaller (larger) than 1 the significance indicators are placed on the left (right) hand side of the measure. The adjusted ratio distributions for 1996 and 1998 are tested for equality using the Kruskal-Wallis test.

	NYSE		Nasdaq	
	1996	1998	1996	1998
Friction Measures				
Bid-Ask Spread Measures				
$Spread	1.76***	1.66***+++	1.72***	1.38***+++
%Spread	1.72***	1.66***	1.67***	1.36***+++
Eff$Spread	1.81***	1.71***+++	1.71***	1.41***+++
Eff%Spread	1.76***	1.70***	1.66***	1.40***+++
LogSpread	1.72***	1.66***	1.67***	1.36***+++
QuoteSlope	1.74***	1.76***	2.17***	2.21***+++
LquoteSlope	***0.97	***0.95	1.06***	1.08***+++
Price Measures				
Price	1.03***	1.01++	1.04***	1.02**++
HiLo	1.72***	1.62***	1.96***	1.76***++
HiLoMdpt	1.74***	1.61***	2.69***	2.82***
Return Measures				
Marsh	1.49***	1.44***	1.65***	***1.23+++
IntraQRet	1.58***	1.62***+	2.59***	1.69***+++
IntraSD	1.75***	1.67***+	1.90***	1.44***+++
IntraSDMdpt	***0.73	***0.74	***1.23	***0.99+++
Activity Measures				
Depth Measures				
AskDepth	**0.94	***0.90	***0.51	***0.62+++
$AskDepth	0.96	***0.90+	***0.53	***0.63+++
BidDepth	**1.02	***0.87	***0.52	***0.63+++
$BidDepth	**1.06	***0.88	***0.53	***0.64+++
LogDepth	***0.93	***0.90+	***0.65	***0.53+++
Depth/Spread	***0.52	***0.52	***0.34	***0.50+++
Volume Measures				
DailyVolume	**1.00	***0.98	***1.11	**1.12+
$DailyVolume	**1.04	**0.98	***1.16	*1.15
NumberTrans	***0.67	***0.62	***0.79	***0.84
VolReturn	***0.78	***0.70	***0.88	***0.91
Size Measures				
MarketCap	1.03***	1.01++	1.03***	0.99+++
TurnoverRate	**1.00	***0.99	***1.17	1.36+
Transaction	***0.73	***0.78+	***0.68	***0.66
$Transaction	***0.75	***0.78	***0.70	***0.67
%InsideSprd	***0.97	***0.95+++	1.12***	***0.93+++
Fsize	1.64	1.21	***0.68	***0.84+
Lsize	1.06	***1.01	***1.00	***1.02

* significant at a level of 10%, ** significant at a level of 5%, *** significant at a level of 1%.
+1996 and 1998 adjusted means significantly different at a level of 10%, ++1996 and 1998 adjusted means significantly different at a level of 5%, +++1996 and 1998 adjusted means significantly different at a level of 1%

Figure 1 Frequency of stock splits in each year from 1993-1998. Stock splits with a split factor of two for one and three for two are shown for each exchange.



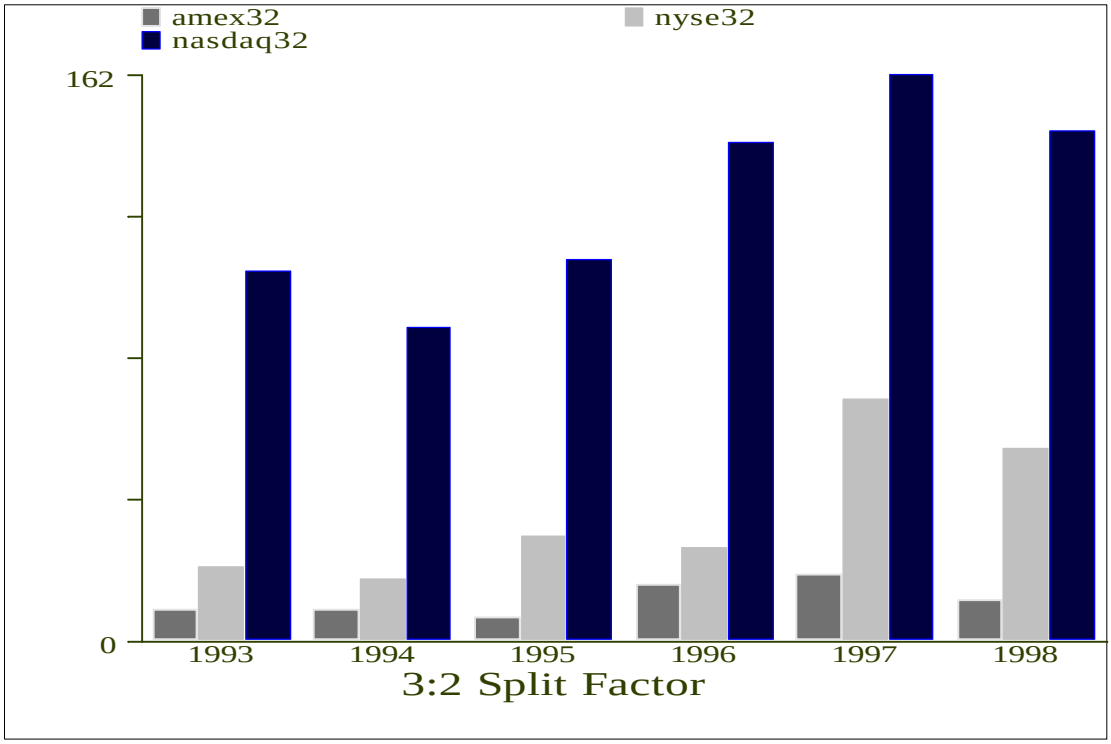


Figure 2 Box and whisker plots for the distribution of the logarithm of the stock price for each of the ten days before and after a stock split. All stock splits are included from 1993-1998. Plots are shown separately for stock splits with a split factor of two for one and three for two and separately for each exchange.

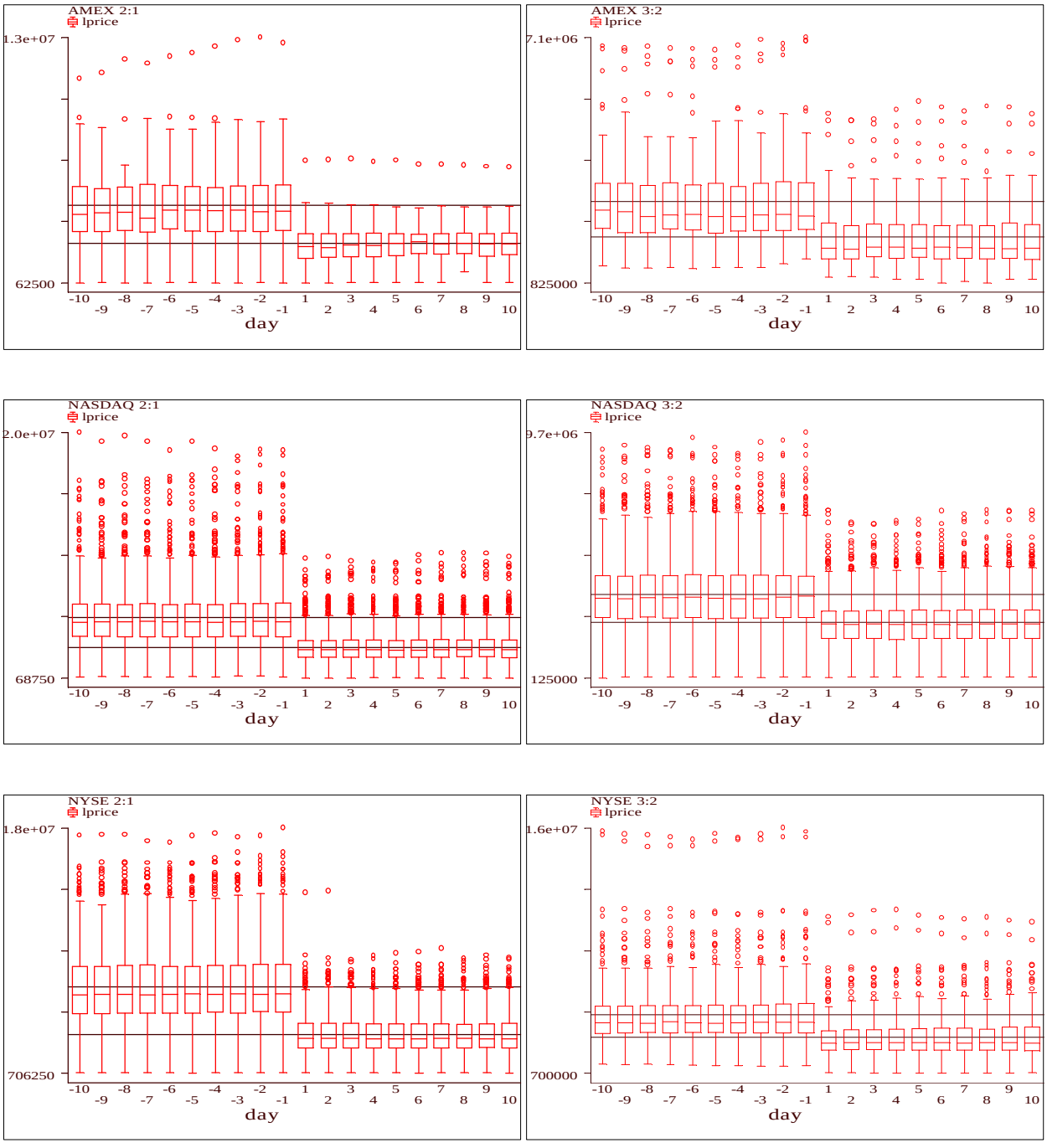


Figure 3 Box and whisker plots for the distribution of the logarithm of ask depth for each of the ten days before and after a stock split. All stock splits are included from 1993-1998. Plots are shown separately for stock splits with a split factor of two for one and three for two and separately for each exchange.

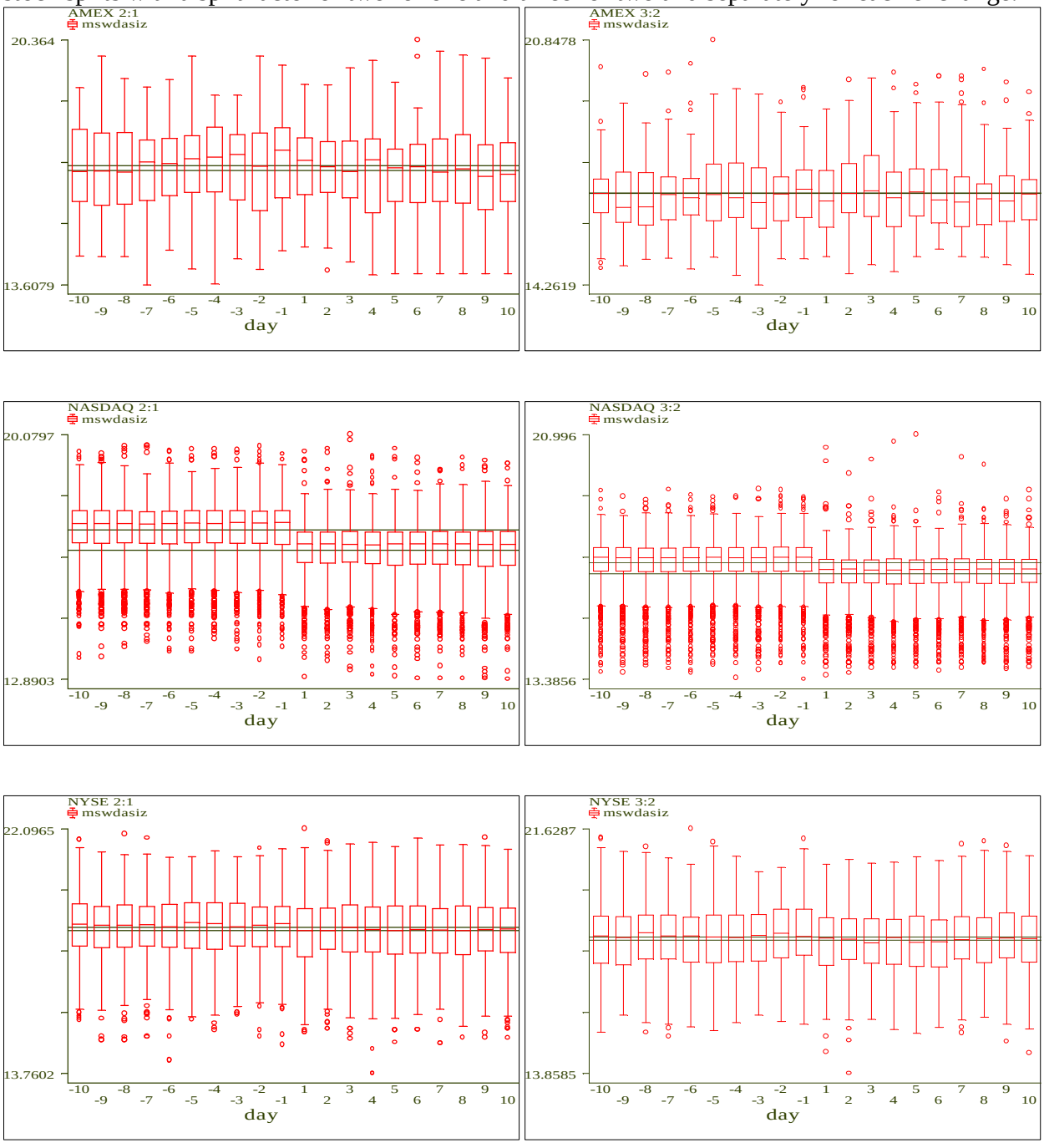


Figure 4 Log Effective Spread Before and After Structural Changes Box and whisker plots for the distribution of the logarithm of the effective spread for each of the ten days before and after a stock split on Nasdaq and the NYSE. Plots of the measure for large stock splits (two for one) are shown separately for 1996 and 1998.