ELSEVIER

Journal of Empirical Finance 10 (2003) 271–303

Journal of EMPIRICAL FINANCE

www.elsevier.com/locate/econbase

Stock splits: implications for investor trading costs

Stephen F. Gray[a,b,*], Tom Smith[c], Robert E. Whaley[a]

[a] *Fuqua School of Business, Durham, N.C. 90120, USA*
[b] *Department of Commerce, UQ Business School, University of Queensland, Brisbane 4072, Australia*
[c] *Australian National University, Canberra 0200, Australia*

Abstract

Stock splits are known to have a negative effect on market quality—while stock prices adjust consistently with the split's scale, the bid/ask spread and market depth do not. Two possible explanations for the relative increase in spread are that (i) splits cause an increase in market maker costs that are passed along to investors or (ii) splits provide a mechanism for market makers to increase excess profits. Using a robust econometric methodology, we find evidence of the latter, which raises questions about the motivation of the splitting practice. We also document that while NASDAQ spreads appear to adjust more fully than those of NYSE/AMEX stocks, NASDAQ spreads are higher in general.

Keywords: Stock splits; Investor trading costs

Academics and practitioners alike continue to be intrigued by the market effects of stock splits. Since the early part of the century, investigators have observed that stock splits tend to be associated with stock price increases.[1] In the first modern-day empirical analysis of the effects of stock splits, Fama et al., 1969 examined 940 stock splits over the period 1927–1959 using monthly returns and found an average abnormal return of 34% over the 30 months preceding the split date and no abnormal return afterward. Lakonishok and Lev (1987) refined the Fama et al. analysis by using daily return data and distinguishing between the split announcement and effective split dates. For their sample of 1015 splits during the period 1963–1982, they find an average abnormal return of 53% in the 5

* Corresponding author. UQ Business School, University of Queensland, Brisbane 4072, Australia. Tel.: +61-7-3365-6586; fax: +61-7-3365-6788.
E-mail address: s.gray@business.uq.edu.au (S.F. Gray).

[1] See, for example, Dice (1928) and Dooley (1933).

0927-5398/02/$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0927-5398(02)00049-X

years preceding the announcement date, with no price increase afterward. These studies, together with a number of others,[2] offer strong and consistent evidence that stock splits tend to occur after a period of positive abnormal performance, with no abnormal performance after the split has been announced.

An equally interesting, albeit less-scrutinized, aspect of the stock split phenomenon is its implications for market liquidity. Market liquidity refers to the ability of the market to absorb investor trading demands quickly and in size. Two important measures of market liquidity are the level and the depth of the quoted bid/ask price spread. Market makers stand ready to provide investors with immediate exchange by quoting the level and the size at the bid (to accommodate investor sales) and at the ask (to accommodate investor purchases).

A number of theoretical and empirical studies have focused on changes in the quoted bid/ask spread around stock splits. The consensus from these studies is that stock splits cause a reduction in market quality. In particular, proportional bid/ask spreads increase, on average, after a split. In this paper, we examine whether this increase is attributable to (i) splits inducing increased market-making costs that are passed along to investors in the form of higher spreads, or (ii) splits providing a mechanism for market makers to increase excess profits at the expense of investors.

Recent research decomposes the market maker's cost structure into three components: order processing costs, inventory holding costs and adverse selection costs. Order processing costs are the direct costs of providing the market-making service including the cost of the exchange seat, floor space rent, computer and information services and so on. Inventory holding costs are the costs associated with holding an inventory of securities including the opportunity cost of the funds tied up and the risk that the value of the inventory will change adversely (with market information or information regarding the specific prospects of the firm). Adverse selection costs are the costs associated with the fact that market makers are exposed to the risk of trading with individuals who are better informed. As we argue in the next section, none of these costs change as a result of a stock split. Indeed, if anything, they are reduced. Consequently, a 2-for-1 stock split should at least halve the quoted bid/ask spread and double the depth of the market at the bid and ask price levels. On the contrary, however, we use a robust econometric methodology to document that investor trading costs (and market maker revenues) increase significantly as a result of a stock split.

This study is divided into six sections. In the first section, we review the literature related to stock splits and models of the bid/ask spread, and lay the foundation for our empirical predictions. Section 2 contains a description of the data that form the basis of our analysis and descriptions of our variable measurements. Section 3 contains a discussion of our major findings regarding market liquidity. Stock splits are shown to increase investor trading costs. Section 4 models the relation between the market maker's bid/ask spread and its cost components. The model is fitted to pre-announcement data and is shown to fit well. When the same model is applied across the pre/post-split sample, however, a significant

[2] For a comprehensive review of the studies that have examined the market effects of stock splits, see Maloney and Mulherin (1992) or Angel (1996).

absolute increase in the dollar bid/ask spread is detected, and this increase is shown not to be attributable to changes in the market maker's costs. This implies that market makers are setting higher bid/ask spreads, and although split-adjusted trading volume is lower after the split, the increased spreads translate into higher excess profits. Finally, Section 5 contains a summary of our major conclusions.

1. Stock splits and models of the bid/ask spread

A number of explanations have been offered as to why firms split their stocks.[3] Most of them are based on the perception that a split increases the stock's liquidity in the marketplace. Some argue that lower stock prices are inherently more "attractive". By splitting, the firm attracts new investors, thereby broadening its ownership base and increasing trading activity. Others argue that by splitting the stock, management is signaling the market that the firm is undervalued. Yet others argue that the firm may use a split as an attention-getting device or that in lowering the stock price, a split results in transaction costs savings.[4]

The evidence regarding whether the market is more or less liquid after the split depends on the measure of liquidity that is used. Some researchers measure market liquidity using dollar trading volume. Using a sample of 25 OTC firms during the period 1968–1976, Copeland (1979) found that dollar trading volume declines. Lamoureux and Poon (1987) reached the same conclusion using a sample of NYSE and AMEX stocks during the period January 1962 to June 1985. Lakonishok and Lev (1987), on the other hand, concluded that the split has no permanent effect on volume. They ascribe the apparent post-split reduction in trading volume to the fact that the pre-split trading volume is abnormally high.

Other investigators measure liquidity using the spread between quoted bid and ask prices. Copeland (1979), for example, examined a sample of 162 OTC firms for the period 1968–1976 and found a significant increase in percentage spread. Conroy et al. (1990) examined the bid/ask spreads around 133 NYSE splits between January 1, 1981 and April 30, 1983, and found a significant increase in the relative bid/ask spread but a significant reduction in the absolute level of the spread. Using a subsample of data in this study, Schultz (1998) found quoted and effective relative spreads increase from the pre- to the post-split dates.

In this study, we also focus on the bid/ask spread around stock splits. We corroborate earlier findings that the relative spread increases, on average, after a split. However, our primary focus in this paper is to determine whether this is due to (i) splits causing an increase in market maker costs, or (ii) splits providing a mechanism for market makers to increase excess profits.

[3] Baker and Gallagher (1980) report the results of a survey of corporate financial managers whose firms experienced a stock split during 1978.

[4] Historically, for example, the per-share trading costs were higher for odd-lot trades (i.e., trades less than a round-lot or 100 shares), so splitting the shares served to reduce the total cost of trading. This argument no longer applies because the odd-lot differential on the NYSE was eliminated in January 1991.

To understand the effect that a stock split should have on market liquidity, we need to consider the cost components of formal models of the market maker's bid/ask spread. In these models of the bid/ask spread, market maker costs generally fall into one of three categories: (a) order processing costs, (b) inventory holding costs and (c) adverse information costs.[5] Order processing costs are those directly associated with providing the market-making service and include costs such as the exchange seat, floor space rent, computer costs, informational service costs, labor costs and the opportunity cost of the market maker's time. Generally speaking, these costs are invariant to trading frequency. Indeed, to our knowledge, the only variable cost on the NYSE is an exchange fee that amounts to less than one-twentieth of a penny per share.[6] When these fixed costs are considered on a per-share basis, however, they will vary inversely with trading activity. The higher the trading activity, the lower the cost per share.

Inventory holding costs are the costs that the market maker incurs while holding an inventory of stocks to supply the market with immediacy. Here, there are two obvious considerations: the cost of the funds used to finance the market maker's inventory and the risk of adverse price movements of the stocks held in inventory. If a stock split has no effect on investor demand, the market maker will not alter his inventory management practice and thus inventory holding costs will remain the same. If the stock split changes investor demand, however, the effect on inventory holding costs is unclear. Holding other factors constant, an increase in the demand for the shares of a stock would probably increase the need for market makers to hold a larger inventory, thereby increasing the financing cost component of inventory holding costs. In addition, a larger inventory likely exposes the market maker's portfolio to more idiosyncratic price risk, also leading to higher inventory holding costs. However, this assumes that the increased demand is long lived. A main argument in support of a stock split says that the split makes the stock more attractive to small investors and will increase the shareholder base. Such an argument, however, leads to increased demand only in the short-run. Presumably, these new shareholders buy and hold. Shortly after the split, investor demand may subside, perhaps to a level lower than pre-announcement demand. Consequently, inventory holding costs will be reduced. Absent a well-defined alternative, we hypothesize that a stock split induces no change in investor demand and consequently no change in inventory holding costs. When bid/ask spreads are considered cross-sectionally, we expect inventory holding costs to vary only with the price risk of the stock. The higher the price risk, the higher the bid/ask spread. In general, the opportunity cost of funds will not matter since market makers do not carry significant inventories of stocks for long periods.

[5] Stoll (1985) categorized the market maker's costs in this fashion. Theoretical and empirical work in the market microstructure area began with Demsetz (1968) and focused exclusively on order processing and inventory holding costs. Tinic (1972), Tinic and West (1972, 1974), Benston and Hagerman (1974), and Stoll (1976, 1978) are among the more notable studies of stock price spreads. Smith and Whaley (1994) examined the behavior of S&P 500 futures spreads. More recently, the emphasis has turned to the costs of adverse selection. Here, the reader is referred to studies such as Copeland and Galai (1983), Glosten and Milgrom (1985) and Admati and Pfleiderer (1988).

[6] George Sofianos of the NYSE kindly provided information regarding the variable cost structure faced by specialists on the NYSE.

The final category is adverse selection costs. These costs arise from the fact that market makers, in providing immediacy, often trade with individuals who are better informed. The relevant question, therefore, is why a stock split would increase or decrease the proportion of informed trading that takes place. Under the ''optimal trading range'' argument, a split should increase the amount of noise (uninformed) trading and thereby reduce adverse selection costs. Under the ''information-signaling'' argument, the entire market becomes ''informed'' about the future prospects of the firm and adverse selection costs are reduced. The null hypothesis, therefore, is that adverse selection costs post-split are no greater than they were pre-announcement. The most commonly used measure of adverse selection costs is the market value of the firm's equity. The larger the firm, the more information available and the less chance of informed trades.

Based on these arguments, it seems unlikely that stock splits cause an increase in market maker costs so as to warrant the increased proportional spread that has been documented in the literature. Ultimately, however, this is an empirical issue. The econometric methodology we develop below allows us to quantify the change in market maker costs around a stock split and to partition the increase in the proportional spread into (i) a component justified by any increase in market maker costs and (ii) a component of excess profits to market makers.

2. Data and variable measurement

To examine the effect of a stock split on the bid/ask spread and the market depth at the bid-and-ask price quotes, we collected information on all NYSE, AMEX and NASDAQ stock splits (greater than or equal to 5-for-4) and stock dividends (greater than 25%) during the years 1993–1996.[7] The split information was taken from the CRSP NYSE/AMEX and NASDAQ daily master files.[8] The CRSP split factor is defined as the number of shares issued for each share owned before the split. A split factor of 1, for example, implies a 2-for-1 stock split, and a factor of 0.25 implies a 5-for-4 split or a 25% stock dividend. Reverse splits were too few to be considered. The CRSP files were also a source of daily returns for the stocks in the sample. For each split, data were compiled for a period extending 2 years before the split announcement date to 1 year after the split effective date.

The primary source for the trade and quote information used in our analyses of stock splits was the NYSE's TAQ files. These files contain time-stamped records of all trades and all quotes for NYSE, AMEX and NASDAQ stocks. Our event window is 40 trading days preceding the announcement of the split—the ''pre-announcement period''—and 40 trading days after the split's effective date—the ''post-split period.'' We also consider trading behavior in the period between the announcement date and the effective date—the ''post-announcement/pre-split period.'' In our sample, the number of days between the announcement and effective date ranged from 3 to 325. Fig. 1 shows the frequency

[7] While the accounting treatments of stock splits and stock dividends differ, we treat them as economically indistinguishable in our investigation.

[8] In the CRSP files, normal, non-taxable stock splits and stock dividends are coded as 5523 and 5533, respectively.

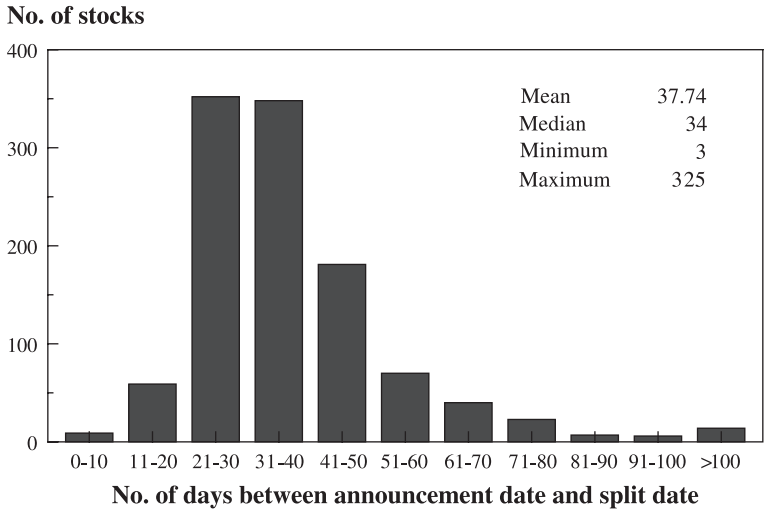

Fig. 1. Frequency of NYSE/AMEX/NASDAQ stock splits (and stock dividends) during 1993–1996 by number of days between the announcement of a stock split and the day the split becomes effective. The figure includes only stock splits of 5-for-4 or greater. Sample size is 1109.

distribution. The median number of days between the split announcement and the split is 34, with 80% of the splits in the range between 21 and 50 days.

The first step in the analysis is to take the trade and quote data and compute a number of descriptive measures for each stock on each trading day. Generally speaking, these measures can be categorized according to whether they are measures of (a) trading activity, (b) the quoted bid/ask spread, (c) market depth, market quality and competition and (d) trading within the spread, the effective spread and market-making revenue. In developing these measures, only trades and quotes from the stock's primary exchange are considered, unless otherwise noted.

2.1. Trading activity measures

The first set of measures focuses on trading activity. Do stock splits enhance trading activity or reduce it? To answer this question, we compute the following measures for each stock on each trading day:

Number of trades during day: the total number of trades during the day[9]
Total shares traded during the day: the total number of shares traded in the day
Dollar value of shares traded during the day: the sum of the dollar value (number of shares times price per share) of all trades during the day

[9] The term, "during the day", refers to all trades executed after the open for the NYSE and AMEX and all trades executed during the day for NASDAQ.

Percent of dollar value of shares traded at open: the dollar value of all trades executed at the open for NYSE/AMEX stocks only[10]
Trade size in shares: the number of shares traded in each trade
Trade size in dollars: the dollar value of the shares traded in each trade.

In addition to the trading activity measures, we report stock price and stock return volatility. The reported stock prices are bid/ask price midpoints (a) at the close of the announcement day, (b) at the close on the day before the split becomes effective and (c) at the open on the effective day. The stock return volatility is computed using the Parkinson (1980) high–low estimator applied to the daily bid/ask midpoint price series.[11]

2.2. Quoted bid/ask spread measures

The arguments presented in the last section suggest that a stock split should directly reduce the size of the quoted bid/ask spreads. To address this issue, we compute several measures of the quoted bid/ask spread including:

Equal-weighted average quoted spread: the average of all bid/ask spreads quoted during the day
Volume-weighted average quoted spread: the average of the quoted bid/ask spreads during the day weighted by the proportion of daily trading volume executed while each pair of quotes was in effect
Median quoted spread: the median of all bid/ask spreads quoted during the day
Equal-weighted average relative quoted spread: the average of all relative bid/ask spreads (i.e., bid/ask spread divided by bid/ask midpoint) quoted during the day
Volume-weighted average relative quoted spread: the average of all relative bid/ask spreads (i.e., bid/ask spread divided by bid/ask midpoint) quoted during the day weighted by the proportion of daily trading volume executed while each pair of quotes was in effect.

2.3. Market depth, market quality and competition measures

One possible encumbrance to a full adjustment of the quoted bid/ask spread commensurate with the size of the stock split is the minimum price variation imposed by the exchanges. During the sample period, stocks on the NYSE priced at greater than $1 were traded in eighths of a dollar.[12] The minimum quoted tick size for AMEX stocks whose prices exceeded $5 was also an eighth. NASD did not restrict trading or quoting in any of

[10] Unlike NYSE and AMEX, the NASDAQ does not have a special opening procedure.

[11] More specifically, stock return volatility is measured by taking the square root of the variance as computed using the Parkinson (1980) high–low estimator, $\ln(\text{High}/\text{Low})^2/4\ln 2$, where High and Low are the high and low values of the bid/ask midpoints during the day.

[12] The NYSE, together with AMEX and the NASDAQ, reduced the minimum price variation of stocks to one-sixteenth in mid-1997. Decimal pricing of all US stocks began in April 2001. For an analysis of the effects of the NYSE's change in minimum price variation, see Bollen and Whaley (1998).

their rules, although quotes on the NASDAQ system were limited to eighths of a dollar if the share price exceeded $10. If the quoted bid/ask spread is currently three-eighths and the stock splits two for one, the only available post-split spread that will not reduce the market maker's pre-split revenue (assuming dollar volume remains constant) is two-eighths.

Minimum price variation, therefore, has the potential of holding quoted bid/ask spreads at higher levels than otherwise expected.[13] Investors may be no worse off, however. With a higher profit margin per share, market makers can provide greater depth at the prevailing bid/ask quotes. For NYSE/AMEX stocks, the specialists may provide increased quantity. In addition, with higher profit margins, limit order traders may also step in, providing yet additional depth. For NASDAQ stocks, existing market makers may choose to provide more size, and/or more market makers may step in.

Ideally, the benefit to investors needs to account for changes in both the quoted bid/ask spread and the depth available at the quotes. To do this, a concept called "market quality" is introduced. To measure market quality, a "quality index" (QI) is defined as:

$$\mathrm{QI}_t = \frac{(\text{depth at bid}_t + \text{depth at ask}_t)/2}{\text{percent quoted spread}_t \times \text{split adjustment}},$$

where the split adjustment equals (a) one prior to the split and (b) one plus the split factor afterward. The percent quoted spread is defined as the quoted bid/ask spread divided by the bid/ask price midpoint, and the split factor is defined as the number of new shares issued for each old share. The depth at the bid and the depth at the ask are measured in thousands of shares. We do not interpret this measure as being the relevant benchmark for all investors. For very small investors, for example, greater depth is not an advantage so the spread alone would be the relevant measure. Thus, we report this quality index as one of a battery of measures to be considered collectively.

Finally, for NYSE/AMEX stocks, a measure of competition is possible. Trading in NYSE and AMEX-listed stocks occurs not only in their primary markets but also on other regional exchanges such as the Chicago Stock Exchange, the Cincinnati Stock Exchange, the Boston Stock Exchange, the Philadelphia Stock Exchange and the Pacific Stock Exchange. On the TAQ database, both primary exchange and consolidated trading volume figures are reported. Competition is measured as one minus the ratio of the primary exchange trading volume to consolidated volume. If spreads are higher in the post-split period, presumably, competition will increase. In summary, the measures of market depth, market quality and competition include:

Depth at the bid: the average of number of shares available for immediate exchange at the prevailing bid price quote[14]

[13] Grossman and Miller (1988) noted that the minimum price variation (tick size) puts a floor on the quoted bid/ask spread.

[14] The publishable limit on the quote system for the shares available at the bid and at the ask is 99,900. Since a reported depth of 99,900 may appear when the size is actually larger, these values are excluded in our computations of average market depth and market quality.

Depth at the ask: the average of the number of shares available for immediate exchange at the prevailing ask price quote
Dollar depth at the bid: the average of the dollar value of shares available for immediate exchange at the prevailing bid price
Dollar depth at the ask: the average of the dollar value of shares available for immediate exchange at the prevailing ask price
Quality index: the average of the ratio of the average depth at the bid and ask price quotes divided by the percent quoted spread (the quantity one plus the split factor also appears in the denominator in the post-split measurement of this variable)
Competition: one minus the ratio of the primary exchange's trading volume to the consolidated trading volume to the consolidated trading volume.

2.4. Trades within the quotes, effective spread and revenue measures

The final set of measures combine trade and quote information. A weakness of the quality index is that it fails to account for trades executed within the prevailing quoted bid and ask prices.[15] To assess the degree to which this occurs, the proportion of daily trades (and the proportion of daily dollar volume) executed within the prevailing bid/ask price quotes is measured. In addition, to adjust the measures of bid/ask spread to account for the fact that trades take place within the prevailing quotes, two measures of the "effective" spread are provided. The effective spread is defined as twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread,[16] that is,

$$\text{Effective spread}_t = 2\left|\text{trade price}_t - \frac{(\text{bid price}_t + \text{ask price}_t)}{2}\right|.$$

Measured in this way, the effective spread will always be less than or equal to the quoted spread. Two measures of the effective spread are computed each day. The equal-weighted (EW) effective spread is an average of the effective spreads (i.e., across all trades) of a stock during the trading day. The volume-weighted (VW) effective spread is an average of the effective spreads, where each spread is weighted by number of shares traded in relation to total daily trading volume.

By definition, market-making revenue equals total investor trading costs.[17] To see this, assume that the fee for the market-making service is infinitesimally small. In such a situation, investors would pay no trading costs because all trades would take place at a

[15] Trades within the quoted bid/ask spread may occur in a variety of ways. Measured by trading volume, "crossed trades" are the largest proportion. These may be trades that are negotiated away from the floor and are crossed once the trade is consummated or trades that are negotiated directly by individuals standing at the specialist's post. System trades may also be executed within the prevailing quotes and usually represent instances were the specialist has "stopped" an order.

[16] This measure of effective bid/ask spread has been used in a number of studies including Christie et al. (1984) and Huang and Stoll (1994).

[17] In the context of this study, investor trading costs are only those costs associated with executing an order through a market maker. Investors also pay a commission to their broker for communicating their trade to the market maker.

level about equal to the current bid/ask price midpoint. Thus, the cost of the market-making service can be thought of as the degree to which the buying (selling) price exceeds (is below) the bid/ask midpoint, or, simply, one-half the effective bid/ask spread. Now, suppose that an investor buys, and then immediately sells, a share of stock. The investor trading costs equal one-half the effective spread on the buy (at the ask price), and one-half the effective spread on the sell (at the bid price), or simply, the amount of the effective spread. The market-making revenue across the two shares traded is, likewise, equal to the bid/ask spread. Thus, the total investor trading costs and the total market-making revenue for a given stock on a given day is the product of the volume-weighted effective spread and the number of shares traded.[18]

In summary, the trades within the quotes and effective spread measures are:

Proportion of trades within the bid/ask quotes: the total number of trades executed at prices within the prevailing bid/ask quotes divided by the total number of trades during the day

Proportion of volume within the bid/ask quotes: the total trading volume executed at prices within the prevailing bid/ask quotes divided by the total trading volume during the day

Equal-weighted average effective spread: the average of all effective spreads computed during the day, where the effective spread is twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread

Volume-weighted average effective spread: the average of all effective spreads during the day weighted by the proportion of daily trading volume executed at that particular spread

Equal-weighted average percent effective spread: the average of all percent effective bid/ask spreads (i.e., effective bid/ask spread divided by bid/ask midpoint) computed during the day, where the effective spread is twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread

Volume-weighted average percent effective spread: the average of all percent effective bid/ask spreads computed during the day weighted by the proportion of daily trading volume executed at that particular spread

Market-making revenue: the volume-weighted effective spread on a particular day times the number of shares traded during the day.

To estimate stock-specific pre-announcement and post-split values of each measure, we average across days. If a stock did not trade in at least 10 of the 40 trading days in the pre-announcement period or in at least 10 of the 40 trading days in the post-split period, it is eliminated from the sample. After completing this exercise, we are left with a total of 1109 stock splits—448 from the NYSE/AMEX and 661 from NASDAQ. Fig. 2 shows the frequency of splits by type. As the figure shows, the dominant split sizes are 2-for-1 (more

[18] Total market-making revenue is an aggregate figure, intended only to measure the approximate amount of revenue generated from all of those making a market in a particular stock on a given day. It is not intended to assign revenues to particular market makers. Even under the NYSE/AMEX specialist systems, multiple market makers may stand at the specialist's post and compete for order flow.

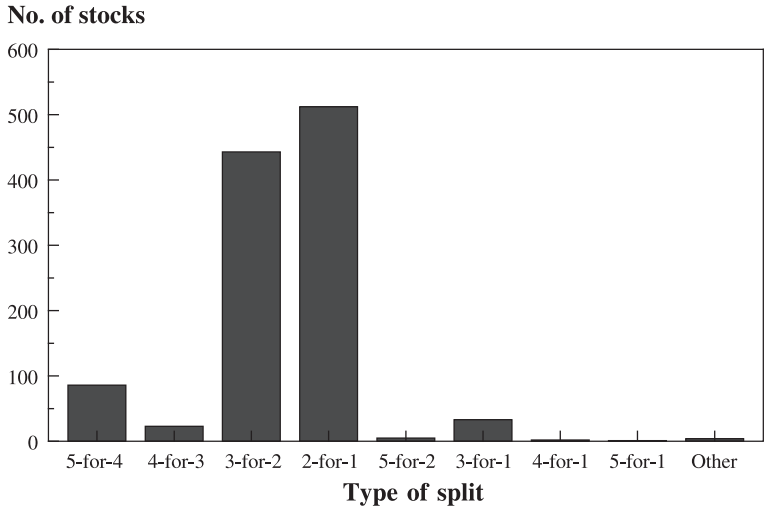

Fig. 2. Frequency of NYSE/AMEX/NASDAQ stock splits (and stock dividends) during 1993–1996 by type of split. The figure includes only stock splits of 5-for-4 or greater. Sample size is 1109.

than 46%) and 3-for-2 (about 40%). Following these with much lower frequencies are 5-for-4, 3-for-1 and 4-for-3.

3. Trading costs before and after stock split

We now turn to describing our preliminary findings. Table 1 contains a summary of the empirical results for the sample of splits that were 5-for-4 or greater. For the full sample, the average split factor is 0.766. This means that on average, about 0.77 shares were awarded for each share owned. The NYSE/AMEX and NASDAQ splits tend to be about the same size, with split factors of 0.769 and 0.765, respectively. The realized price adjustment is the ratio of the closing bid/ask midpoint on the day before the effective day to the opening bid/ask midpoint of the effective day less one. The average realized price adjustment across all stocks in the sample is 0.751, very close to the average split factor. The same applies for the NYSE/AMEX and NASDAQ subsamples.

3.1. Analysis of trading activity

A number of interesting results appear in the trading activity panel of Table 1. The average share price at the close across all stocks in the sample on the day before the split is $44.31, and the average share price at the open on the split day is $24.98. This post-split opening price corresponds closely to its expected level. Dividing the average, pre-split closing price, $44.31, by one plus the average split factor, 1.766, yields $25.09. The post-split average opening prices for the NYSE/AMEX and NASDAQ subsamples also correspond closely to their expected levels based on the average split factors. Interestingly,

Table 1
Summary of trade and quote data in the 40 trading days preceding the split announcement, in the days following the announcement but preceding the split and the 40 trading days after the effective split date

	All stocks				NYSE/AMEX stocks				NASDAQ stocks			
Number of splits	1109				448				661			
Split factor	0.766				0.769				0.765			
Realized price adjustment	0.751				0.760				0.746			
	Average levels				Average Levels				Average levels			
	Pre-announcement	Post-announcement/ pre-split	Post-split	Relative change (%)	Pre-announcement	Post-announcement/ pre-split	Post-split	Relative change (%)	Pre-announcement	Post-announcement/ pre-split	Post-split	Relative change (%)
Trading activity measures												
Share price	44.31	43.43	24.98*	− 43.6	48.42	47.82	26.95*	− 44.3	41.52	40.44	23.64*	− 43.1
Stock return volatility	27.90%	26.80%	35.80%*	28.3	23.51%	21.97%	29.71%*	26.4	30.87%	30.08%	39.92%*	29.3
Number of trades during day	122.97	138.37	176.51*	43.5	74.11	82.81	98.13*	32.4	156.08	176.08	229.63*	47.1
Total shares during day	181.10	186.94	294.87*	62.8	135.73	140.10	233.60*	72.1	211.86	218.74	336.40*	58.8
Dollar value of shares during day	10,039.86	11,459.54	10,253.24	2.1	8395.59	9139.96	8407.87	0.1	11,154.28	13,034.05	11,503.97	3.1
Percent of dollar volume at open					4.33%	4.55%	4.37%	0.8				
Average trade size in shares	1.443	1.335	1.719*	19.2	1.474	1.400	1.892*	28.3	1.422	1.290	1.603	12.7
Average trade size in dollars	57.53	58.67	44.24*	− 23.1	67.79	68.02	53.81*	− 20.6	50.57	52.32	37.76*	− 25.3
Quoted bid/ask spread measures												
Equal-weighted quoted spread	0.4829	0.5122	0.4294	− 11.1	0.2505	0.2500	0.2203	− 12.0	0.6403	0.6902	0.5711	− 10.8
Volume-weighted quoted spread	0.4852	0.5140	0.4318	− 11.0	0.2565	0.2563	0.2268	− 11.6	0.6403	0.6890	0.5708	− 10.9
Median quoted spread	0.4819	0.5109	0.4257*	− 11.7	0.2460	0.2452	0.2118	− 13.9	0.6417	0.6913	0.5706	− 11.1

Equal-weighted percentage quoted spread	1.65%	1.56%	2.15%*	29.7	0.76%	0.70%	1.00%*	32.0	2.27%	2.14%	2.93%*	29.2
Volume-weighted percentage quoted spread	1.66%	1.56%	2.16%*	29.7	0.77%	0.72%	1.02%*	32.5	2.27%	2.14%	2.93%*	29.1
Market depth, market quality and competition measures												
Bid quote depth (in shares)					2.86	2.67	4.51*	57.6				
Ask quote depth (in shares)					3.36	3.49	5.54*	64.7				
Bid quote depth (in dollars)					132.38	130.39	132.99	0.5				
Ask quote depth (in dollars)					158.14	170.42	165.29	4.5				
Quality index					8.19	8.56	5.16*	− 37.1				
Competition					12.03%	12.90%	13.67%	13.6				
Trades within quotes, effective spread and market-making revenue measures												
Percent shares traded within quotes	38.06%	37.69%	37.22%	− 2.2	33.35%	33.19%	30.16%	− 9.6	41.25%	40.73%	42.01%	1.8
Percent of dollars traded within quotes	38.06%	37.68%	37.21%	− 2.2	33.35%	33.20%	30.16%	− 9.6	41.25%	40.73%	42.00%	1.8
Equal-weighted effective spread	0.3623	0.3942	0.3220	− 11.1	0.1550	0.1539	0.1381	− 10.9	0.5028	0.5573	0.4467	− 11.2
Volume-weighted effective spread	0.3442	0.3723	0.3038*	− 11.7	0.1764	0.1762	0.1563	− 11.4	0.4580	0.5053	0.4037	− 11.8
Equal-weighted relative effective spread	1.25%	1.20%	1.62%*	29.2	0.48%	0.44%	0.63%*	32.6	1.78%	1.72%	2.29%*	28.6
Volume-weighted relative effective spread	1.19%	1.14%	1.53%*	28.8	0.54%	0.50%	0.71%*	32.8	1.63%	1.57%	2.09%*	27.9
Market-making revenue	24.36	26.77	34.33*	40.9	10.02	11.73	15.31*	52.9	34.08	36.99	47.22*	38.5

Stock splits or stock dividends of 5-for-4 or greater are used. The sample contains all splits of NYSE, AMEX and NASDAQ shares during 1993 – 1996. The split factor is defined as the number of shares awarded for each share already owned (e.g., a 5-for-4 split has a split factor of 0.25). Trade and quote data are from the NYSE TAQ database. The values reported in the cells of the table are averages across stocks. The value for each stock is the average across the days in the pre-announcement, post-announcement/pre-split and post-split periods. Volume (depth) and dollar volume (depth) are reported in 1000s. The quality index is the average depth at the bid/ask quotes divided by the relative spread (times the split factor in the post-split period). The effective spread is twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread.

NASDAQ firms tend to split their shares at lower price levels than NYSE/AMEX stocks. The average pre-split closing price for the NASDAQ stocks is $40.44, less than 85% of the average pre-split closing price of $47.82 for the NYSE/AMEX stocks. A possible explanation for this phenomenon is the one-eighth of a dollar minimum price variation imposed by the NYSE/AMEX. NASDAQ-traded stocks have no such restriction. Consequently, NASDAQ-listed firms may choose to split at lower price levels in order to maintain the "attractiveness" of the stock.

Stock return volatility appears to increase as a result of the split. In the pre-announcement period, the annualized standard deviation of stock return is 27.90% across all stocks in the sample, and, in the post-split period, the standard deviation is 33.80%. This 28.3% increase is significant in a statistical sense, in spite of the fact that we control for the effect of bid/ask price bounce on return volatility by computing returns based on bid/ask midpoints. This evidence is consistent with a recent study by Koski (1998), who shows that, in the period 1987–1989, stock splits induced a significant increase in return volatility computed using bid prices. Splits cause increased stock return volatility even after accounting for micro-structural effects.

The trading activity results in Table 1 indicate that the stock split has no discernible impact on dollar trading volume. While the average number of trades each day increases by 43.6% from the pre-announcement to the post-split period (i.e., from 122.69 to 176.14), the average dollar value of shares traded over the day increases by only 2.1% (i.e., from $10.040 million to $10.253 million) and is insignificant in a statistical sense. It is interesting to note, however, that the announcement of the split generates abnormal trading volume up until the time the split becomes effective. The average dollar value of shares traded each day between the announcement and the effective day is $11.460 million, a significant increase from the pre-announcement level of $10.040 million.

The fact that the split does not cause a change in the dollar value of shares traded together with the fact that there are more trades and more shares traded after the split implies that the dollar value of each trade is smaller after the split. Indeed, as Table 1 shows, the average trade size falls from $57,530 to $44,240, a decline of 23.1%. This evidence is consistent with both the notion that the split enhances the stock's attractiveness to small investors and the notion that the split reduces (rather than increases) market liquidity.

Finally, it is worth noting that there is little change in the proportion of trading at the open for the NYSE/AMEX stocks. If a trade is executed at the open, the cost of the bid/ask spread is avoided. If the bid/ask spread incurred on trades executed during the day is not reduced proportionately with share price at the time of a split, the implied increase in trading costs may induce investors to trade at the open. The average proportion of daily dollar trading volume executed at the open is 4.33% before the split and 4.37% afterward. This increase is insignificant in a statistical sense.

3.2. Analysis of quoted bid/ask spreads

The summary of absolute quoted bid/ask spreads provided in Table 1 is also interesting in a number of respects. First, the equal-weighted average quoted spread for the full sample of splits is 48.3 cents (about four-eighths) in the pre-announcement period. With such a high spread level, the potentially binding influence of the exchange's minimum tick

size may be less of an issue than expected. With an average pre-announcement spread of 48.3 cents and an average split factor of 0.766, the expected post-split spread is 27.35 cents, considerably below the 42.94 cent spread realized. Fig. 3 shows the distribution of average median quoted spreads before and after the stock split. While the figure illustrates clearly that the median quoted spread has fallen as a result of the split, the drop appears to be less than one-eighth on average. The results using the equal-weighted quoted spread and the volume-weighted quoted spread are similar qualitatively.

Unlike the absolute quoted spread, the average relative quoted spread increases dramatically as a result of the split. The average relative quoted spread for the full sample, for example, is 1.65% before the split and 2.15% afterward—a 29.7% increase. This increase is significant in a statistical sense. The results also indicate a consistent pattern across exchanges. The increase in the average relative spread is 32.0% for NYSE/AMEX stocks and 29.2% for NASDAQ stocks. It is interesting to note, however, that the average relative quoted spreads are higher for NASDAQ stocks than for the NYSE/AMEX stocks both before and after the split.

3.3. Analysis of market depth, market quality and competition

Market depth and market quality can only be measured for the sample of NYSE/AMEX stocks. As a matter of practice, NASDAQ reports market depth of 1000 shares for all stocks. On face appearance, depth appears to increase after the split, from an average of 2860 shares to 4510 shares at the bid and an average of 3360 shares to 5540 shares at the ask. In both cases, these increases are well in excess of 50%. When depth is measured in

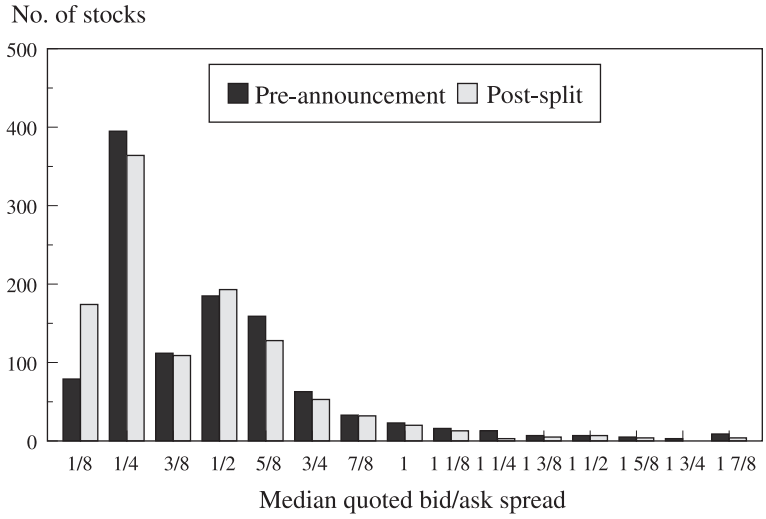

Fig. 3. Frequency of average median quoted bid/ask spreads in the pre-announcement and post-splits periods for stock splits (and stock dividends) during 1993–1996 by size of spread. The figure includes only stock splits of 5-for-4 or greater. Sample size is 1109.

dollar value, however, market depth appears unchanged as a result of the split, a 0.5% increase at the bid level and 4.5% increase at the ask level.

The evidence thus far indicates that the quoted bid/ask spread falls and the dollar market depth at the bid and ask quotes stays the same as a result of a stock split for NYSE/AMEX stocks. In an attempt to combine these results into a single measure of market quality, we compute the ''quality index''. Recall that this metric assesses market liquidity before and after the split. The higher the index, the more liquid the market. Turning to the third panel of Table 1, we find that the quality index falls from 8.19 in the pre-announcement period to 5.16 in the post-split period, a decrease of 37.1%. Clearly, the stock split has adversely affected this measure of trading costs that incorporates both spread and depth.

Finally, the last row in the third panel contains a measure of the degree of competition. Recall that competition is defined as one minus the ratio of the primary exchange trading volume to consolidated volume. The table indicates that prior to the split announcement, 12.03% of the total number of shares were traded away from the primary exchange, where the primary exchange is either NYSE or AMEX. Although not reported in the table, the frequency distribution is negatively skewed (i.e., the greatest mass of the distribution lies to the left), with more than 96% of stocks having less than 25% of their volume traded away from the primary exchange. What this means is that there is little inter-exchange competition. Moreover, the split induces little change. Even after the split, only 13.67% of volume trades away from the primary exchange. What this figure does not show, however, is any change in the number of market makers standing at the specialist's post on the primary exchange's floor.

3.4. Analysis of trading within the quotes, the effective spread and revenue

One possible criticism of the quality index is that it does not account for trading that occurs within the prevailing bid/ask price quotes. In the final panel of Table 1, the average proportion of trades within the quotes are reported. Overall, the percent of trades executed within the quoted spread remains relatively unchanged—38.06% of trades are executed within the quotes before the split and 37.22% after. For the NYSE/AMEX stocks, there is a modest decline of 9.6%, indicating, perhaps, that quoted spreads have been reduced thereby reducing the market maker's flexibility of trading within the spread. For the NASDAQ stocks, however, the proportion of trades within the quotes actually increases by 1.8%.

The effective spread is a better measure of trading costs than the quoted spread, since it accounts for the trades that occur within the prevailing bid/ask price quotes. In Table 1, we report the both the equal-weighted and volume-weighted effective spread levels. The volume-weighted effective spread in the pre-announcement period is 34.42 cents for the full sample, well below the volume-weighted quoted spread of 48.52 cents. The effective spread falls from 34.42 to 30.38 cents, a decline of about 11.7%. Note that the percent decrease in effective spread is roughly the same order of magnitude as it was for the quoted spread. The subsample results show similar size percentage decreases in the volume-weighted spread. They also show that the effective spreads are much larger for NASDAQ stocks than for NYSE/AMEX stocks.

Relative effective spreads are also reported in the last panel of Table 1. The volume-weighted relative effective spread for the overall sample is 1.19% in the pre-announcement

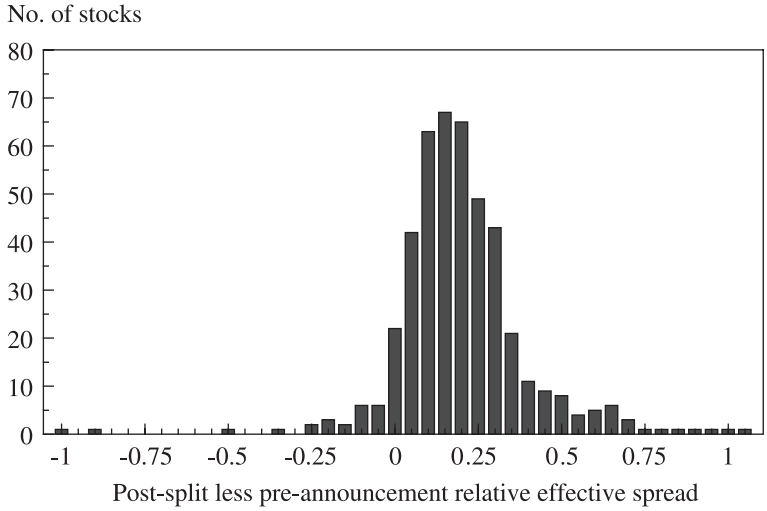

Fig. 4. Frequency of the difference between the post-split and pre-announcement volume-weighted percent relative effective spreads for NYSE/AMEX stocks for stock splits (and stock dividends) during 1993–1996. The figure includes only stock splits of 5-for-4 or greater. Sample size is 448.

period. This means that for every dollar used for investment, an investor can expect a 1.19 cent trading cost. From the pre-announcement to the post-split period, the volume-weighted relative spread rises by 28.8% and is statistically significant. Figs. 4 and 5 show the frequency distributions of the difference between the pre-announcement and

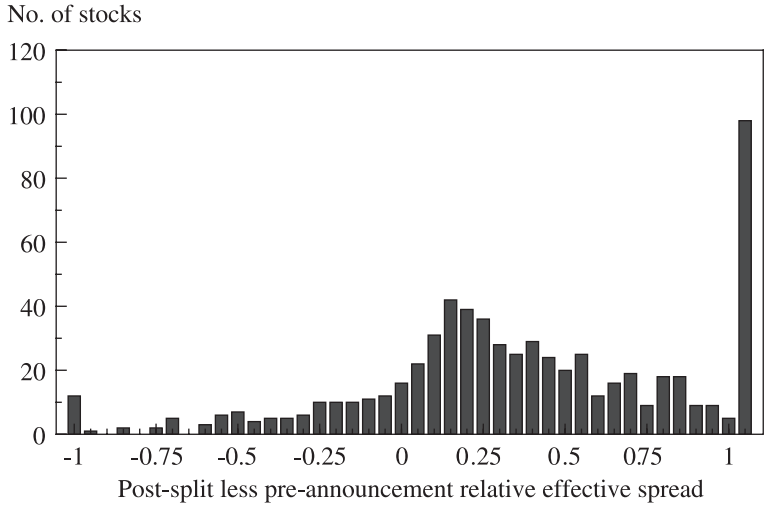

Fig. 5. Frequency of the difference between the post-split and pre-announcement volume-weighted percent relative effective spreads for NASDAQ stocks for stock splits (and stock dividends) during 1993–1996. The figure includes only stock splits of 5-for-4 or greater. Sample size is 661.

Table 2
Summary of trade and quote data in the 40 trading days preceding the split announcement, in the days following the announcement but preceding the split and the 40 trading days after the effective split date

	All stocks				NYSE/AMEX stocks				NASDAQ stocks			
Number of splits	554				231				323			
Split factor	1.079				1.069				1.086			
Realized price adjustment	1.058				1.052				1.062			
	Average levels				Average Levels				Average levels			
	Pre-announcement	Post-announcement/pre-split	Post-split	Relative change (%)	Pre-announcement	Post-announcement/pre-split	Post-split	Relative change (%)	Pre-announcement	Post-announcement/pre-split	Post-split	Relative change (%)
Trading activity measures												
Share price	55.37	54.25	27.03*	− 51.2	61.31	60.55	29.87*	− 51.3	51.12	49.72	24.99*	− 51.1
Stock return volatility	29.97%	29.44%	39.94%*	33.2	23.41%	22.01%	30.83%*	31.7	34.66%	34.77%	46.45%*	34.0
Number of trades during day	179.80	206.35	270.09*	50.2	101.06	116.55	137.14	35.7	236.10	270.78	365.17	54.7
Total shares during day	257.31	267.87	444.47*	72.7	180.84	188.61	328.18*	81.5	311.99	324.73	527.64*	69.1
Dollar value of shares during day	16,071.39	18,628.82	16,123.72	0.3	12,904.04	14,210.65	12,436.36	− 3.6	18,336.59	21,798.37	18,760.82	2.3
Percent of dollar volume at open					4.42%	4.69%	4.36%	− 1.3				
Average trade size in shares	1.430	1.330	1.827*	27.8	1.494	1.408	2.082*	39.4	1.385	1.274	1.645	18.8
Average trade size in dollars	70.95	72.86	50.04*	− 29.5	85.94	86.64	64.49*	− 25.0	60.23	62.97	39.71*	− 34.1
Quoted bid/ask spread measures												
Equal-weighted quoted spread	0.5084	0.5391	0.4125*	− 18.9	0.2504	0.2486	0.2090	− 16.5	0.6930	0.7475	0.5580	− 19.5
Volume-weighted quoted spread	0.5107	0.5407	0.4148*	− 18.8	0.2563	0.2561	0.2156	− 15.9	0.6927	0.7448	0.5572	− 19.6
Median quoted spread	0.5070	0.5381	0.4074*	− 19.6	0.2442	0.2443	0.1982	− 18.8	0.6950	0.7488	0.5570*	− 19.8

Equal-weighted percentage quoted spread	1.48%	1.36%	2.02%*	36.5	0.58%	0.53%	0.85%*	47.0	2.12%	1.94%	2.85%*	34.5
Volume-weighted percentage quoted spread	1.48%	1.36%	2.02%*	36.5	0.59%	0.55%	0.88%*	47.3	2.12%	1.94%	2.85%*	34.3
Market depth, market quality and competition measures												
Bid quote depth (in shares)					3.02	2.81	5.61*	85.8				
Ask quote depth (in shares)					3.59	3.67	6.86*	91.1				
Bid quote depth (in dollars)					171.79	169.61	178.27	3.8				
Ask quote depth (in dollars)					206.68	220.48	219.40	6.2				
Quality index					10.70	11.09	6.26*	− 41.5				
Competition					11.98%	13.00%	14.18%	18.4				
Trades within quotes, effective spread and market-making revenue measures												
Percent shares traded within quotes	36.93%	36.29%	35.60%	− 3.6	32.08%	31.89%	27.87%	− 13.1	40.40%	39.45%	41.13%	1.8
Percent of dollars traded within quotes	36.93%	36.28%	35.59%	− 3.6	32.08%	31.89%	27.87%	− 13.1	40.40%	39.44%	41.12%	1.8
Equal-weighted effective spread	0.3844	0.4210	0.3120*	− 18.8	0.1561	0.1530	0.1324	− 15.2	0.5477	0.6133	0.4406*	− 19.6
Volume-weighted effective spread	0.3683	0.4019	0.2961*	− 19.6	0.1796	0.1802	0.1507	− 16.1	0.5032	0.5610	0.4002*	− 20.5
Equal-weighted relative effective spread	1.13%	1.07%	1.54%*	35.9	0.37%	0.34%	0.55%*	47.2	1.68%	1.59%	2.25%*	34.1
Volume-weighted relative effective spread	1.09%	1.02%	1.47%*	35.1	0.43%	0.40%	0.62%*	46.4	1.56%	1.46%	2.07%*	32.9
Market-making revenue	35.39	40.12	51.53*	45.6	13.65	17.08	21.27*	55.8	50.93	56.65	73.17	43.7

Stock splits or stock dividends of 2-for-1 or greater are used. The sample contains all splits of NYSE, AMEX and NASDAQ shares during 1993 – 1996. The split factor is defined as the number of shares awarded for each share already owned (e.g., a 2-for-1 split has a split factor of 1.00). Trade and quote data are from the NYSE TAQ database. The values reported in the cells of the table are averages across stocks. The value for each stock is the average across the days in the pre-announcement, post-announcement/pre-split and post-split periods. Volume (depth) and dollar volume (depth) are reported in 1000s. The quality index is the average depth at the bid/ask quotes divided by the relative spread (times the split factor in the post-split period). The effective spread is twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread.

post-split volume-weighted relative effective spreads for the NYSE/AMEX and NASDAQ samples. Clearly, the mass of the distributions lies to the right of zero in both figures. Indeed, for the NASDAQ sample, 98 firms have volume-weighted relative effective spreads that increase by 100 basis points or more. Stock splits dramatically increase trading costs from an investor's standpoint.

One-half of the effective bid/ask spread can be interpreted as either the investor's trading cost per share or the market maker's revenue per share. Thus, the product of the one-half of the volume-weighted effective spread and the daily trading volume in shares is a measure of market-making revenue per day. The average daily revenue is $24,360 before the announcement of the split and $34,330 after the split became effective—an increase of 40.9%. The subsample results show increases of 52.9% for the NYSE/AMEX stocks and 38.5% for the NASDAQ stocks. In summary, stock splits appear to generate considerable additional revenue for market makers. Whether this additional revenue is justified in terms of increased market-making costs is investigated in Section 4.

3.5. Summary of analysis of 2-for-1 splits

A possible reason for the lack of adjustment of trading costs to the stock split is that many of the splits are too small to warrant a change given that prices have a minimum increment of one-eighth. To test this proposition, we re-examine the summary statistics presented in Table 1, but this time using only splits of 2-for-1 or greater. A total of 554 such splits are contained in the sample: 231 NYSE/AMEX-traded and 323 NASDAQ-traded. The results of this investigation are reported in Table 2.

The interpretations of the results in Table 2 are similar in spirit to those of Table 1. The average total number of trades and total number of shares traded for the overall sample increase by 50.2% and 72.7%, respectively, while the dollar volume of trading remains basically unchanged. Naturally, this implies that average trade size has fallen. Indeed, the average dollar trade size also falls by 29.5% as opposed to 23.1% when all splits 5-for-4 or greater were considered. Again, this evidence supports the notion that the split enhances the stock's attractiveness to small investors.

The summary of quoted bid/ask spreads provided in Table 2 indicates that the equal-weighted average quoted spread for full sample of splits is 50.84 cents before the split announcement and 41.25 cents after the split becomes effective. The drop is 18.9% and is significant in a statistical sense. Similar results are shown for the volume-weighted average quoted spread and the average median quoted spread. The equal-weighted average relative quoted spread measures rise over 36%.

Market depth for NYSE/AMEX stocks, when measured in number of share, increases dramatically after the split—85.8% at the bid and 91.1% at the ask. When depth is measured in dollar value, however, market depth appears relatively unchanged—a 3.8% increase at the bid and 6.2% increase at the ask. Neither increase is significant statistically. The quality index falls by over 41.5% and is significant. Two-for-one splits appear to have an adverse effect on market quality. Interestingly, the competition measure increases more in the sample of splits 2-for-1 or greater than it did in the sample of splits 5-for-4 or greater—18.4% versus 13.6%. Apparently, the higher the split ratio, the greater the post-split revenue opportunity.

The final panel in Table 2 reports a number of measures of trading within the quotes, effective spreads and market-making revenue. As was the case with the 5-for-4 splits, the average proportion of trades executed within the quoted spread is reduced. The reduction is small, however. In the full sample, the reduction is less than 4%. For the NYSE/AMEX sample, the reduction is over 13%, reflecting the fact no trades in stocks with post-split spreads of one-eighth can occur within the quotes on NYSE and AMEX. The percent of trades within the posted quotes is slightly higher for NASDAQ stocks post-split than pre-announcement.

The volume-weighted average effective spread falls from 36.83 to 29.61 cents. While this represents a decline of 19.6%, it is well below the minimum 50% drop that is expected for splits of 2-for-1 or greater. Viewed differently, the volume-weighted relative effective spread rises by 35.1%. If the spread and price per share were adjusted proportionately by the same factor, the relative spread would remain unchanged. Instead, investor trading costs appear to have been increased by 35.1%. Market-making revenue also shows a dramatic increase. Recall that we define market-making revenue as one-half the volume-weighted effective spread during the day times the total shares traded. The average daily revenue is $35,390 across the days in the pre-announcement period and $51,530 across the days in the post-split period—an increase of 45.6%. The increase is 55.8% for the NYSE/AMEX sample and 43.7% for the NASDAQ sample.

4. Assessing the change in the spread's components

In Section 2, we described the market maker's cost structure as having three components: order processing costs, inventory holding costs and adverse selection costs. These costs must be incorporated in the market maker's bid/ask spread. In addition, depending upon the barriers to entry for potential competitors in providing the market-making service, the level of the market maker's spread may also include a premium for market (i.e., monopoly or cartel) power. Finally, discreteness in the bid/ask spread (stock prices could only be multiples of one-eighth of a dollar during the sample period) may impact the observed spread. In Section 3, we began measuring the various cost components before and after a stock split in an attempt to gather information to assess how stock splits affect trading costs. In this section, we formally model the market maker's bid/ask spread and test whether stock splits have induced a change in the spread, holding other factors constant. To begin, we identify empirically the relation between the volume-weighted effective spread[19] and market maker costs before the split announcement for both the NYSE/AMEX and the NASDAQ samples. We then turn to isolating the effect of the stock split on the market maker's spread.[20] We allow both for a shift in the level of the spread as well as for shifts in the responsiveness of the spread to its cost components.

[19] While the results reported in this section use volume-weighted effective spread as the dependent variable, the results are qualitatively no different using volume-weighted quoted spread.

[20] Spreads can be measured on a per-share basis (sometimes called the "absolute spread") or a per dollar basis (sometimes called the "relative spread"). We explain below our preference for measuring spreads and explanatory variables on a per-share basis.

Finally, we attempt to distinguish between market power and minimum tick size as possible explanations for the apparent increase in spread size after the stock split.

4.1. Model specification

In identifying an appropriate pre-split regression structure, we use proxies for order processing and inventory holding costs.[21] Order processing costs are the direct costs of providing the market-making service including the cost of the exchange seat, floor space rent, computer and information services and so on. Since these costs are largely fixed, their effect on the bid/ask spread should be inversely related to the trading activity. We, therefore, use the inverse of the total number of shares traded per day, $1/TV_i$, to proxy for order processing costs.

Inventory holding costs are the costs associated with holding an inventory of securities. These include the opportunity cost of the funds tied up in holding an inventory of the security and the risk that the value of the inventory may change adversely (due to new market information or new information regarding the specific prospects of the firm). The opportunity cost of funds is not a major concern, however. Market makers strive to have minimal inventory at the end of the day, thereby minimizing carrying costs. In addition, if a position is held overnight, it is as likely to be a short position as a long position, in which case, interest is earned rather than paid. The risk of change in the value of the market maker's position, however, is important independent of whether or not the position is long or short. Adverse price movements in one direction or the other are costly, and the market maker must be compensated for bearing this risk. In terms of setting the dollar spread per share, the most relevant measure of risk is the standard deviation of the stock price changes (dubbed "stock price volatility"), $\sigma_{\Delta S_i}$. This measure is computed by multiplying the standard deviation of stock return (defined earlier) by share price.

The market maker spread may also depend upon the level of competition for the market-making service. The larger the number of market makers, the greater is the competition and the lower the bid/ask spread, other things equal. Of course, the ability of competition to play a role in reducing the spread depends upon the ability of new market makers to enter the competition for the market-making service, an issue that we return to later in this section.

Past empirical work examining the determinants of the bid/ask spread have generally not included competition as an explanatory variable. The reason is that data for such a variable are generally not publicly available. With the advent of TAQ data, calculating a

[21] Recall that earlier, we discussed adverse selection costs as being a component of the bid/ask spread. Adverse selection costs are the costs associated with the fact that market makers are exposed to the risk of trading with well-informed individuals. In our regression model, we do not include a proxy for adverse selection for two reasons. First, it is hard to envision how the stock split will change the amount of informed trading taking place. Indeed, if anything, there should be more noise trading in the post-split period. Second, there is no good proxy for adverse selection. The most commonly used measure for adverse selection is the market value of the shares outstanding. The intuition is the larger the firm, the greater the publicly available information, and the less adverse selection. As Tables 2 and 3 show, the price per share of the stock adjusts exactly according to the split factor, as does the number of shares outstanding. Hence, there is no change in this adverse selection proxy by definition.

competition variable is now possible. The TAQ data reports both primary and consolidated trading volume. Thus, for stocks whose primary market is either the NYSE or the AMEX, we measure competition, $COMP_i$, as one minus the ratio of the trading volume on the primary exchange to the consolidated trading volume. Because NASDAQ stocks trade only on NASDAQ, no such measure of competition is possible for NASDAQ stocks.

In summary, we hypothesize that the market maker's effective bid/ask spread is a function of order processing costs, inventory holding costs and the degree of competition. We use the inverse of trading volume of the stock to proxy for order processing costs, stock price volatility to measure inventory holding costs and one minus the ratio of primary trading volume to consolidated trading volume to proxy for competition (with the competition variable included in the NYSE/AMEX sample only). Thus, our formal model is

$$SPRD_i = \alpha_0 + \alpha_1(1/TV_i) + \alpha_2\sigma_{\Delta S_i} + \alpha_3 COMP_i + \varepsilon_i, \quad (1)$$

where the responsiveness of the bid/ask spread to changes in the cost/competition components are given by the coefficients, α_1, α_2 and α_3. The intercept term, α_0, can be interpreted as an amalgam of the effects of market power and the minimum tick size.

Note that Eq. (1) is specified in terms of the absolute spread (the spread per share) rather than the relative spread (the spread per dollar of stock price). We do this for three reasons. First, measures for all of our explanatory variables are available on a per-share basis. We measure trading volume in terms of shares rather than dollars, we measure stock volatility in terms of changes in stock price rather than stock return, and we hypothesize that competition impacts the spread on a per share basis. Second, the intercept term is naturally defined in per-share terms. Recall that this intercept incorporates the effects of two components: market power and the minimum tick size. While market power could be measured on either a per-share or per-dollar basis, the effect of stock price discreteness is naturally measured on a per-share basis—the minimum spread is one eighth of a dollar for all stocks, regardless of their price. Third, scaling all of these measures by stock price (effectively a weighted least-squares regression) introduces potential econometric problems, as described by Kronmal (1993).

Regression model Eq. (1) is estimated across the average daily values of the variables of each stock across the 40 trading days prior to the announcement of the split. Table 3 contains the results. For the NYSE/AMEX stocks, all regression coefficients appear with the expected signs. Spreads increase with the inverse of trading volume and the standard deviation of stock price change, and decrease with the level of competition. All coefficients are significant at less than a 0.01% probability level. The adjusted R^2 is 29.40%, considerably lower than the values reported in other investigations of stock spreads. The reason is that we perform the regression using absolute spread, rather than relative spread, as the dependent variable for the reasons explained above. For now, it is important to recognize that the estimated correlation between the squared residual term and the stock price, reported in the last column of the table, is insignificant (e.g., the estimated correlation is only 0.0067 for the NYSE/AMEX sample). The absence of meaningful correlation provides assurance about our chosen regression specification (see Kronmal, 1993).

Table 3
Summary of cross-sectional regression results for the volume-weighted absolute and relative effective bid/ask spreads

Number of observations	R^2	Adjusted R^2	Parameter estimates (significance) of the coefficients					Residual variance correlation
			α_0	α_1	α_2	α_3	α_4	
NYSE/AMEX sample								
448	0.2987	0.2940	0.149018	0.000486	0.002981	− 0.201657		0.0067
			0.0000	0.0000	0.0000	0.0000		0.8872
448	0.8928	0.8918	0.000659	0.000318	0.002924	− 0.136373	0.125316	0.1278
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0068
448	0.8876	0.8868		0.000317	0.00411	− 0.176556	0.135983	0.1418
				0.0000	0.0000	0.0000	0.0000	0.0026
NASDAQ sample								
661	0.2882	0.2860	0.268677	0.003212	0.008021			0.0621
			0.0000	0.0000	0.0000			0.1110
661	0.6596	0.6580	0.000252	0.002673	0.014669		0.217782	0.1437
			0.7134	0.0000	0.0000		0.0000	0.0002
661	0.6595	0.6585		0.002685	0.015115		0.219192	0.1443
				0.0000	0.0000		0.0000	0.0002

Regression variables are averages of the daily variable values across the 40 trading days preceding the split announcement. All stock splits (and stock dividends) of 5-for-4 or greater on the NSYE, AMEX and NASDAQ during the period 1993–1996 are used. The regression specifications for the absolute ($SPRD_i$) and relative ($RSPRD_i$) spreads are

$$\text{Absolute spread regression}: \quad \text{SPRD}_i = \alpha_0 + \alpha_1(1/\text{TV}_i) + \alpha_2\sigma_{\Delta S_i} + \alpha_3\text{COMP}_i + \varepsilon_i$$

$$\text{Relative spread regression}: \quad \text{RSPRD}_i = \alpha_0 + \alpha_1(1/\$\text{TV}_i) + \alpha_2\sigma_{R_i} + \alpha_3(\text{COMP}_i/S_i) + \alpha_4(1/S_i) + v_i$$

where $1/TV_i$ is the inverse of number of shares traded (in 000s), $\sigma_{\Delta S_i}$ is the standard deviation of daily stock price changes, and $COMP_i$ is one minus the ratio of primary trading volume to consolidated traded volume. The variables in the relative spread regression are the same as those in the absolute spread regression divided by the share price, S_i. The residual variance correlation is the correlation of the squared residuals from the fitted regression and share price. The values below the parameter estimates are the probabilities that the coefficients are not different from zero.

The NASDAQ sample results are similar. The coefficients on the inverse of trading volume and stock price volatility again have the expected sign and are highly significant in a statistical sense. The coefficient estimate on the inverse of trading volume is not as high as the NYSE/AMEX sample, indicating, perhaps, that NASDAQ market makers are less willing to pass on the savings from reduced order processing costs per share. In addition, the coefficient of stock price volatility is higher, indicating that NASDAQ market makers charge a greater premium for bearing risk. In addition, all of this is coupled with the fact that the intercept term is considerably higher for the NASDAQ regression than for the NYSE/AMEX regression, 26.9 cents versus 14.9 cents, respectively. While direct comparison is undermined by the fact that the NYSE/AMEX regression also includes a competition variable, the average of the competition variable in the NYSE/AMEX is only 0.12033. This implies that competition reduces the average spread by 0.201657×0.12033 or about 2.4 cents on average, considerably less than the difference between the intercept

terms. In other words, the fixed cost component of the effective bid/ask spread appears much larger for NASDAQ stocks than for NYSE/AMEX stocks. This may be driven by a variety of factors including market power, the minimum tick size and the exclusion of a competition variable in the NASDAQ regression.

4.2. The effect of stock splits

We now turn to investigating the effect of stock splits on the market maker's spread. Regression (1) serves as the basis of our analysis. To account for the split, we pre-multiply the pre-announcement variables, except for competition, by the inverse of one plus the split factor, that is,

$$\begin{aligned}\mathrm{SPRD}_i d_{1,i} = {} & \alpha_0 + \alpha_1(1/\mathrm{TV}_i)d_{1,i} + \alpha_2\sigma_{\Delta S_i}d_{1,i} + \alpha_3\mathrm{COMP}_i + \alpha_4 d_{2,i} \\ & + \alpha_5(1/\mathrm{TV}_i)d_{2,i} + \alpha_6\sigma_{\Delta S_i}d_{2,i} + \alpha_7\mathrm{COMP}_i d_{2,i} + \varepsilon_i, \end{aligned} \tag{2}$$

where the dummy variables are:

$$d_{1,i} = \begin{cases} \frac{1}{1+SFAC_i}, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases} \quad \text{and}$$

$$d_{2,i} = \begin{cases} 0, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases}.$$

Note that with the adjustment of the pre-announcement variables, the null hypothesis of no change in the effective bid/ask spread is preserved.

The regression results are reported in Table 4. Turning first to the NYSE/AMEX regression results, note that the responsiveness of the bid/ask spread to the different spread cost components has not changed. The full regression (2) results show that the coefficients of the dummied post-split variables are not meaningfully different from zero. The coefficient of the dummy in the full model is estimated to be 0.033489 and is statistically significant. In other words, the absolute level of bid/ask spread has increased. What this says is that market makers are not fully reducing the bid/ask spreads to their predicted levels, perhaps, as a result of the market power of the specialist, or perhaps due to the minimum available tick size. In further analysis below, we seek to discriminate between these competing explanations.

The NASDAQ results are similar. The dominant effect resulting from the split appears to be the increase in the absolute level of the spread. The coefficient of the dummy that equals zero in the pre-announcement period and 1 in the post-split period is 0.087421 and is statistically significant. The coefficient on the dummied inverse of trading volume is also significantly positive, indicating that NASDAQ market makers are charging more per share for order processing costs in the post-split period than they were in the pre-announcement period. The coefficient of the risk variable is insignificantly different from zero. What remains in the analysis is an attempt to distinguish

Table 4
Summary of cross-sectional regression results for the volume-weighted absolute effective bid/ask spread

Number of observations	R^2	Adjusted R^2	Parameter estimates (significance) of the coefficients							
			α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7
NYSE/AMEX sample										
896	0.4772	0.4748	0.079416	0.000504	0.003199	− 0.070464	0.043508			
			0.0000	0.0000	0.0000	0.0003	0.0000			
896	0.4794	0.4753	0.082942	0.000540	0.002907	− 0.095165	0.036489	− 0.000053	0.000459	0.044980
			0.0000	0.0000	0.0000	0.0009	0.0000	0.3623	0.4797	0.2504
NASDAQ sample										
1322	0.3303	0.3288	0.170761	0.003032	0.005804		0.109869			
			0.0000	0.0000	0.0000		0.0000			
1322	0.3337	0.3312	0.181763	0.002594	0.005363		0.087421	0.000789	0.000828	
			0.0000	0.0000	0.0003		0.0000	0.0118	0.6275	

Regression variables are averages of the daily variable values across the 40 trading days preceding the split announcement and the 40 trading days after the split becomes effective. All stock splits (and stock dividends) of 5-for-4 or greater on the NSYE, AMEX and NASDAQ during the period 1993–1996 are used. The regression specification for the absolute spread (SPRD_i) is

$$\mathrm{SPRD}_i d_{1,i} = \alpha_0 + \alpha_1(1/\mathrm{TV}_i)d_{1,i} + \alpha_2\sigma_{\Delta S_i}d_{1,i} + \alpha_3\mathrm{COMP}_i + \alpha_4 d_{2,i} + \alpha_5(1/\mathrm{TV}_i)d_{2,i} + \alpha_6\sigma_{\Delta S_i}d_{2,i} + \alpha_7\mathrm{COMP}_i d_{2,i} + \varepsilon_i$$

where $1/\mathrm{TV}_i$ is the inverse of number of shares traded (in 000s), $\sigma_{\Delta S_i}$ is the standard deviation of daily stock price changes and COMP_i is one minus the ratio of primary trading volume to consolidated traded volume. The dummy variables are:

$$d_{1,i} = \begin{cases} \frac{1}{1+\mathrm{SFAC}_i}, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases} \quad \text{and} \quad d_{2,i} = \begin{cases} 0, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases}$$

The values below the parameter estimates are the probabilities that the coefficients are not different from zero.

among the possible explanations for the size and significance of the increased spread in the post-split period.

4.3. Minimum tick size

The results of the previous subsection show that effective bid/ask spreads in the post-split period are higher than are predicted by our model. One possible explanation is that the bid/ask spread is held at an artificially high level due to the minimum tick size applied to bid/ask quotes. In the case of the stocks during our sample period, the minimum tick size for price quotes was one-eighth. The effect of this constraint may be particularly onerous for the NYSE/AMEX sample, whose pre-announcement bid/ask spreads are relatively smaller.

To investigate the effects of the minimum tick size, we rerun the regressions using only those stocks with average daily median quoted bid/ask spreads of at least two-eighths during the pre-announcement period. Thus, we eliminate stocks with pre-split spreads that are so small that the minimum tick size prevents them adjusting by the predicted amount. The results are reported in Table 5. For ease of comparison, the results using the full samples are also reported. The table shows that our original results are robust. Eliminating the stocks with average median quoted bid/ask spreads of less than two-eighths has little effect on the estimated coefficients. Even though the number of observations is reduced by more than half for the NYSE/AMEX sample, for example, the magnitudes of the coefficient estimates on the different cost components and the adjusted R^2 remain comparable to those for the full sample. The results for the NASDAQ regression are qualitatively similar. It seems that even after attempting to account for the effects of tick size, there is a pronounced increase in the level of the effective bid/ask spread resulting from the stock split.

4.4. The effect of competition

The results thus far indicate that effective bid/ask spreads do not fully adjust to the size of the stock split even when the split adjustment is not encumbered by the minimum tick size. Before ascribing the increased bid/ask spread to market power, however, we reconsider the NASDAQ results in which no competition variable was used. Unlike the NYSE/AMEX markets, barriers to entry to making markets for NASDAQ stocks are relatively low. If the market-making rents are indeed higher in the post-split period, it should not be surprising to see the number of market makers increase as a result of the stock split.

As noted earlier, the main problem with conducting an analysis of market maker entry is that data documenting the number of market makers has not been publicly available. For this study, the NASD made available "market participant" data for NASDAQ stocks during 1996. These data include the trading volume of each market maker in a particular stock during a given month. For purposes of our analysis, we compare the number of market makers and their total trading volume in the full month preceding the month of the split announcement with the number of market makers and their total trading volume in the full month after the month the split becomes effective. If the split announcement date was

Table 5
Summary of cross-sectional regression results for the volume-weighted absolute effective bid/ask spread

Number of observations	R^2	Adjusted R^2	Parameter estimates (significance) of the coefficients				
			α_0	α_1	α_2	α_3	α_4
NYSE/AMEX Sample							
896	0.4772	0.4748	0.079416	0.000504	0.003199	− 0.070464	0.043508
			0.0000	0.0000	0.0000	0.0003	0.0000
368	0.4797	0.4740	0.090432	0.000532	0.003979	− 0.083597	0.047205
			0.0000	0.0000	0.0000	0.0009	0.0000
NASDAQ sample							
1322	0.3303	0.3288	0.170761	0.003032	0.005804		0.109869
			0.0000	0.0000	0.0000		0.0000
1256	0.3266	0.3250	0.178630	0.002896	0.005988		0.112349
			0.0000	0.0000	0.0003		0.0000

Regression variables are averages of the daily variable values across the 40 trading days preceding the split announcement and the 40 trading days after the split becomes effective. All stock splits (and stock dividends) of 5-for-4 or greater on the NSYE, AMEX and NASDAQ during the period 1993–1996 and with average median pre-split quoted spreads at least equal to two-eighths are used. The regression specification for the absolute spread ($SPRD_i$) is

$$\mathrm{SPRD}_i d_{1,i} = \alpha_0 + \alpha_1 (1/\mathrm{TV}_i) d_{1,i} + \alpha_2 \sigma_{\Delta S_i} d_{1,i} + \alpha_3 \mathrm{COMP}_i + \alpha_4 d_{2,i} + \varepsilon_i$$

where $1/\mathrm{TV}_i$ is the inverse of number of shares traded (in 000s), $\sigma_{\Delta S_i}$ is the standard deviation of daily stock price changes and COMP_i is one minus the ratio of primary trading volume to consolidated traded volume. The dummy variables are:

$$d_{1,i} = \begin{cases} \frac{1}{1+\mathrm{SFAC}_i}, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases} \quad \text{and}$$

$$d_{2,i} = \begin{cases} 0, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases}$$

The values below the parameter estimates are the probabilities that the coefficients are not different from zero.

February 15 and the split effective date was March 3, for example, we compare the trading activity in the month of January with the month of April. With such a data selection rule, we consider all splits of 5-for-4 or greater during the months February to November 1996. We have 210 such splits in our NASDAQ sample.

The first panel of Table 6 contains summary statistics. During the month before the split announcement date, the average (median) number of market makers was 33.44 (25), with trading volume of 4.4 million shares. During the full month following the split date, the average (median) number of market makers was 41.72 (31.5), with trading volume of 7.2 million shares. The increase in the average number of market makers is 8.28 and is significant at less than the 0.01% probability level. The average percent increase in the number of market makers is nearly 35. It is also worth noting that if the post-split trading volume is adjusted for the split factor, the trading volume in the post-split period is below that in the pre-announcement period, consistent with the full sample results reported in Table 1.

Table 6
Summary of descriptive statistics and cross-sectional regression results for the volume-weighted absolute effective bid/ask spread

	Month before split announcement		Month after split announcement			Change in no. of market makers					
	Number of market makers	Trading volume in shares	Number of market makers	Trading volume in shares	Adjusted trading volume	Absolute change	Relative change				
Mean	33.44	4,440,535	41.72	7,157,626	3,859,165	8.28	34.78%				
Median	25	1,790,838	31.5	2,820,866	1,666,468						
Probability						0.0000	0.0000				
Number of observations	R^2	Adjusted R^2	Parameter estimates (significance) of the coefficients								
			α_0	α_1	α_2	α_3	α_4	α_5	α_6	α_7	
Pre-split sample only											
210	0.2824	0.2720	0.241491	0.001665	0.013850	− 0.002759					
			0.0000	0.0000	0.0000	0.0000					
Pre/post-split sample											
420	0.3025	0.2958	0.262374	0.001799	0.012512	− 0.003152	0.114420				
			0.0000	0.0000	0.0000	0.0000	0.0000				
420	0.3071	0.2953	0.241492	0.001665	0.01385	− 0.002759	0.140944	0.000378	− 0.001337	− 0.000639	
			0.0000	0.0007	0.0000	0.0000	0.0013	0.5991	0.7182	0.4319	

Regression variables are averages of the daily variable values across the 40 trading days preceding the split announcement and the 40 trading days after the split becomes effective. All stock splits (and stock dividends) of 5 − for − 4 or greater on the NSYE, AMEX and NASDAQ during the period February 1996 to November 1996 are used. The regression specification for the absolute spread ($SPRD_i$) is

$$\mathrm{SPRD}_i d_{1,i} = \alpha_0 + \alpha_1(1/\mathrm{TV}_i)d_{1,i} + \alpha_2\sigma_{\Delta S_i}d_{1,i} + \alpha_3\mathrm{COMP}_i + \alpha_4 d_{2,i} + \alpha_5(1/\mathrm{TV}_i)d_{2,i} + \alpha_6\sigma_{\Delta S_i}d_{2,i} + \alpha_7\mathrm{COMP}_i d_{2,i} + \varepsilon_i$$

where $1/\mathrm{TV}_i$ is the inverse of number of shares traded (in 000s), $\sigma_{\Delta S_i}$ is the standard deviation of daily stock price changes and COMP_i is the number of market makers. The dummy variables are:

$$d_{1,i} = \begin{cases} \frac{1}{1+\mathrm{SFAC}_i}, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases} \quad \text{and} \quad d_{2,i} = \begin{cases} 0, & \text{if pre} - \text{announcement date} \\ 1, & \text{if post} - \text{effective date} \end{cases}$$

The values below the regression parameter estimates are the probabilities that the coefficients are not different from zero.

The second panel of Table 6 reports the regression results for this NASDAQ subsample. The first regression is fitted to pre-announcement data and uses the number of market makers as a measure of competition. The regression results are consistent with those reported for the NASDAQ sample in Table 3. The adjusted R^2 and the estimated intercept terms, for example, are of the same orders of magnitude in the two regressions. The coefficients on the inverse of trading volume and the standard deviation of stock price changes remain positive and significant in a statistical sense. The regression results reported in Table 6, however, include the competition variable. Its coefficient is negative and highly significant. The implication is, of course, that as the number of market makers increase, the effective bid/ask spread decreases. The question that now arises is whether the inclusion of the missing competition variable will alter our assessment of the breakdown between fixed and variable effects.

The results for the pre/post-split regressions are also reported in the second panel of Table 6. The first regression includes a dummy variable equal to zero in the pre-announcement period and 1 in the post-split period. The second regression also includes dummy variable slope shifters for the independent variables. Turning to the second regression first, none of the estimates for the post-split independent variables are statistically significant. This means that there is no meaningful difference between how the effective spread responds to changes in the independent variables from the pre-announcement regime to the post-split regime. The only difference between pre- and post-split bid/ask spreads, even after accounting for the increased competition, is a windfall increase in the absolute level. The effective bid/ask spreads are approximately $0.14 per share higher than predicted in the post-split period for the full regression model ($0.11 per share when the insignificant variables are dropped). Apparently, spreads do not adjust to competitive levels in the aftermath of a stock split.

4.5. Market maker revenue estimates and summary

Holding other factors constant, a stock split should reduce the bid/ask spread by a factor equal to the inverse of one plus the split factor. The analysis in this section shows that the adjustment is less than expected and is unrelated to changes in order processing costs, inventory holding costs and/or competition. Moreover, the less than competitive reduction in bid/ask spread does not appear to be as a result of a binding effect of the minimum tick size, as the regression tests produce virtually identical results when stocks with pre-announcement median quoted spreads below two-eighths are eliminated. The windfall increase in the spread, however, does not necessarily imply increased market maker profits. Trading volume must be taken into account. The question is whether market maker revenue, which equals one-half the spread times trading volume, rises or falls.

To answer this question, we rely on effective spreads predicted by the fitted model,

$$\mathrm{SPRD}_i d_{1,i} = \hat{\alpha}_0 + \hat{\alpha}_1 (1/\mathrm{TV}_i) d_{1,i} + \hat{\alpha}_2 \sigma_{\Delta S_i} d_{1,i} + \hat{\alpha}_3 \mathrm{COMP}_i + \hat{\alpha}_4 d_{2,i}, \tag{3}$$

where the dummy variables are as defined for Eq. (2). For each stock, we take one-half the predicted spreads in the pre-announcement and post-split periods, and multiply by the respective trading volumes, and then we sum across stocks in the pre-announcement and post-split periods. For the NYSE/AMEX sample, the predicted market maker revenue is $5.5 million per day across all shares traded in the pre-announcement period and is $7.9 million in the post-split period—an increase of nearly 45%. For the

NASDAQ sample, market maker revenue averages $31.7 million per day in the pre-announcement period and $43.0 million per day in the post-split period—an increase of about 36%.

Clearly, total market-making revenue increases in both the NYSE/AMEX and NASDAQ markets as a result of stock splits. The relative increase in revenues for NASDAQ stocks is smaller than for NYSE/AMEX, perhaps, reflecting lower barriers to entry for market making on NASDAQ. Nonetheless, for both the NYSE/AMEX and NASDAQ markets, the series of tests conducted in this section indicate that the increased revenue is excess profit resulting from market power. The only competing explanation is that the post-split bid/ask spread is "fair" and that market makers were losing money during the pre-split period, but this seems unlikely. There was nothing stopping market makers from charging fair (i.e., higher) spreads in the pre-split period.

5. Summary and conclusions

This study investigates the effects of stock splits on the liquidity of the stock market. The sample consists of all NYSE, AMEX and NASDAQ stock splits (and stock dividends) of 5-for-4 or greater in 1993–1996. We focus on multiple measures of the bid/ask spread size, trading volume, market depth and market quality in the 40 trading days before a split is announced, the period between the announcement day and the effective day and the 40 trading days after the stock split becomes effective. Among the findings are that quoted bid/ask spreads fall and market depth (in number of shares) rises, but neither as much as would be expected given the size of the split factor. Indeed, market quality falls significantly.

Our central empirical analysis focuses on the volume-weighted effective spread and its determinants in the pre-announcement and post-split periods. We model the market maker's bid/ask spread as a function of his order processing and inventory holding costs as well as the degree of competition in the market for an individual stock, and then estimate the model across stocks. Our key finding is that bid/ask spreads are higher than predicted by our model in the post-split period. Since the model's predictions account for changes in costs and competition, the abnormal spreads translate into increased investor trading costs (or, alternatively, increased market maker excess profits), independent of whether or not the minimum tick size is holding the spreads at artificially high levels. In the interest of completeness, however, we rerun our analysis on stocks whose pre-announcement median quoted bid/ask spreads were at least two-eighths and find qualitatively similar results. Stock splits increase investor trading costs.

Acknowledgements

The authors are grateful for the comments and suggestions by Jeff Fleming, F. Douglas Foster, Bruce Grundy, Chris Kirby, Bruce Lehman, Christine Martini, Barbara Ostdiek, and seminar participants at the AGSM Accounting and Finance Camp, the Sloan School of

Management at MIT, the Owen Graduate School of Management at Vanderbilt University, the National University of Singapore, and the 1999 Asia-Pacific Finance Association Conference in Melbourne, Australia.

References

Admati, A., Pfleiderer, P., 1988. A theory of intraday trading patterns: volume and price variability. Review of Financial Studies 1, 3–40.

Angel, J.J., 1996. Tick size, share prices, and stock splits. Journal of Finance 52, 655–681.

Baker, H., Gallagher, P., 1980. Management's view of stock splits. Financial Management 9, 73–77.

Benston, G., Hagerman, R., 1974. Determinants of bid–ask spreads in the over-the-counter market. Journal of Financial Economics 1, 3364–3553.

Bollen, N.P.B., Whaley, R.E., 1998. Are "teenies" better? Journal of Portfolio Management 25, 10–24.

Christie, W., Harris, J., Schultz, P., 1984. Why did NASDAQ market makers stop avoiding odd-eighth quotes. Journal of Finance 49, 1841–1860.

Conroy, R., Harris, R., Benet, B., 1990. Effect of stock splits on bid–ask spreads. Journal of Finance 45, 1285–1295.

Copeland, T., 1979. Liquidity changes following stock splits. Journal of Finance 34, 115–142.

Copeland, T., Galai, D., 1983. Information effects on the bid–ask spread. Journal of Finance 38, 1457–1469.

Demsetz, H., 1968. The cost of transacting. Quarterly Journal of Economics 82, 33–53.

Dice, C.A., 1928. The Stock Market. A.W. Shaw.

Dooley, J.C., 1933. Characteristics and procedure of common stock split-ups. Harvard Business Review (April), 316–326.

Fama, E.F., Fisher, L., Jensen, M., Scholes, M., 1969. The adjustment of stock prices to new information. International Economic Review 10, 1–21.

Glosten, L., Milgrom, P., 1985. Bid, ask and transaction prices in a specialist market with heterogenously informed investors. Journal of Financial Economics 14, 71–100.

Grossman, S., Miller, M., 1988. Liquidity and market structure. Journal of Finance 43, 617–633.

Huang, R., Stoll, H.R., 1994. Dealer versus auction markets: a paired comparison of execution costs on NASDAQ and the HYSE. Journal of Financial Economics 41, 313–357.

Koski, J.L., 1998. Measurement effects and the variance of returns after stock splits and stock dividends. Review of Financial Studies 11, 143–162.

Kronmal, R.A., 1993. Spurious correlation and the fallacy of the ratio standard revisited. Journal of the Royal Statistical Society 156 (Series A), 379–392.

Lakonishok, J., Lev, B., 1987. Stock splits and stock dividends: why, who, and when. Journal of Finance 42, 913–932.

Lamoureux, C., Poon, P., 1987. The market reaction to stock splits. Journal of Finance 42, 1347–1370.

Maloney, M.T., Mulherin, J.H., 1992. The effects of splitting on the ex: a microstructure reconciliation. Financial Management 21, 44–59.

Parkinson, M., 1980. The extreme value method for estimating the variance of the rate of return. Journal of Business 53, 61–65.

Schultz, P., 1998. Stock splits, tick size, and sponsorship. Working paper, University of Notre Dame (November).

Smith, T., Whaley, R.E., 1994. Assessing the costs of regulation: The case of dual trading. Journal of Law and Economics 37 (April), 215–246.

Stoll, H.R., 1976. Dealer inventory behavior: an empirical investigation of NASDAQ stocks. Journal of Financial and Quantitative Analysis 11, 350–380.

Stoll, H.R., 1978. The pricing of security dealer services: an empirical study of NASDAQ stocks. Journal of Finance 33, 1153–1172.

Stoll, H.R., 1985. The Stock Exchange Specialist System: An Economic Analysis. Monograph Series in Finance and Economics. Salomon Brothers Center, New York University.

Tinic, S., 1972. The economics of liquidity services. Quarterly Journal of Economics 86 (February), 79–93.

Tinic, S., West, R., 1972. Competition and the pricing of dealer services in the over-the-counter market. Journal of Financial and Quantitative Analysis 7 (June), 1707–1728.

Tinic, S., West, R., 1974. Marketability of common stocks in Canada and the U.S.: a comparison of agent versus dealer-dominated markets. Journal of Finance 29 (June), 729–745.