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ARE "TEENIES" BETTER?

ABSTRACT

On June 5th, 1997, the NYSE voted to adopt a system of decimal price quoting, changing its longstanding practice of using 1/8ths. While the system does not go into place until the turn of the century, the NYSE began quoting stock prices in 1/16ths, so-called "teenies," as an intermediate step on June 24th, 1997. This paper examines whether the refined price gradation has reduced trading costs on the NYSE. The evidence indicates that both bid/ask spreads and market depth at the prevailing bid/ask quotes have fallen. On balance, investor trading costs have dropped overall, with the largest gains being experienced for low price shares and for small trade sizes.

Journal of Portfolio Management 25, 10-24, Fall 1998

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ARE "TEENIES" BETTER?

On June 5th, 1997, the New York Stock Exchange (NYSE) voted to adopt a system of decimal price quoting, changing its longstanding practice of using 1/8ths. While the decimal system does not go into place until the turn of the century, the NYSE began quoting stock prices in 1/16ths, so-called "teenies," as an intermediate step on June 24th, 1997. The move to reduce the tick size[1] was prompted by competition from NASDAQ, the American Stock Exchange, and the regional exchanges, and from the threat of congressional action to force the issue.

The NYSE's move to a smaller tick size offers a rare opportunity to evaluate empirically competing arguments regarding an "optimal tick size." The arguments in favor of a larger, "significant," tick are threefold. First, significant ticks may encourage market liquidity. The larger is the tick size, the greater is the minimum quoted bid/ask spread.[2] If the tick size is binding, then a larger tick size will generate more market maker revenue, thereby increasing the number of individuals willing to engage in market making and providing the market with enhanced liquidity. The strength of this argument depends on the extent to which the tick size is a binding constraint on the bid/ask spread. Just because spreads can be reduced to as little as the tick size does not mean they have to be. The London Stock Exchange, for example, has no minimum tick size, and quoted bid/ask spreads are typically five pence or greater. Second, significant ticks reduce bargaining costs. A larger tick size reduces the number of possible prices at which to trade, thereby reducing bargaining costs and increasing operational efficiency.[3] Third, significant ticks provide stronger priority rules in the order book. If a tick is too low, some investors may offer marginally better prices, thereby gaining priority and discouraging other investors from placing limit orders.[4]

The primary argument in favor of a smaller tick size is that smaller ticks may encourage market liquidity. Presumably investors are interested in after-transaction-cost returns. If the

[1] The tick size is the minimum increment that a price may move.

[2] The bid/ask spread is the difference between the prices at which the market maker is willing to buy (the "bid") and sell (the "ask") and represents the revenue per share that the market maker earns for providing the investors with immediacy in trading. This term was originally coined by Demsetz (1968).

[3] See, for example, Grossman and Miller (1988) and Brown, Laux, and Schacter (1991).

current tick size is binding, a lower tick size will mean lower trading costs, thereby encouraging existing investors to trade more frequently and/or new investors to begin trading.

The debate over whether there is an optimal tick size clearly has important implications for exchanges. Holding other factors constant, exchanges earn revenue in direct proportion to trading volume. Since the arguments for and against a significant tick size suggest a relation between tick size and trading volume, they also suggest a relation between tick size and exchange revenue.

The ideal time to test theories concerning a market's optimal tick size is when the tick size is changed. Unfortunately, changes to the tick size are made infrequently, so direct tests are sparse. Bacidore (1997) examined the effect of the change to decimal pricing for stocks traded on the Toronto Stock Exchange. He reports that, for stocks over $5 (Cdn), effective spreads dropped by 26 percent for stocks cross-listed on other exchanges and 20 percent for non cross-listed stocks. For the U.S. stock markets, the only direct evidence has appeared in the popular press. The *Wall Street Journal* (June 25, 1997) reported that quoted bid/ask spreads on the NYSE fell by more than 10 cents a share from the day before to the day after the change to $1/16^{th}$s for some large market capitalization stocks. Spreads also dropped by more than 5 cents a share for some low- and mid-capitalization stocks. The same article reported that NASDAQ spreads dropped 10 percent during the first five days after the switch to $1/16^{th}$s on June 2, 1997 versus the nineteen days beforehand and that AMEX spreads dropped 7.6 percent after a switch to $1/16^{th}$s on May 7, 1997.

Indirect evidence has also been reported. Angel (1997) argues that there is an optimal stock price level for a given tick size that balances the positive and negative impact of tick size on spreads, depth, and liquidity. He argues that the remarkably stable average price of NYSE stocks this century is the result of the constant tick size. Firms can use stock split decisions in order to maintain the optimal tick-to-price ratio. Harris (1994) uses data well before the NYSE's switch to $1/16^{th}$s and runs a series of regressions to predict how spreads, depth, and trading volume would change if the NYSE lowered the tick size from $1/8^{th}$ to $1/16^{th}$.

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[4] This argument has been advanced by Harris (1994) and Angel (1997).

The purpose of this study is to measure changes in the trading environment and investor welfare resulting from the NYSE's switch to 1/16ths on June 24, 1997. The study is divided into five sections. In the first, we provide a detailed description of the data and the measurements we use to assess market impact. Section II contains an analysis of the effects of the switch to 1/16ths at an aggregate market level. In section III, we stratify the stocks in the sample by price per share and dollar trade size to determine whether stocks were affected differentially by the switch to 1/16ths. Section IV contains an analysis of NYSE market share. In the last section, we summarize the major findings of the study.

I. Data and Variable Measurement

To investigate the effects of the NYSE's move to 1/16ths, we examine all 2,852 common stocks that traded on the NYSE during June 1997. Trade and quote data for these stocks were collected for the 20 trading days before (i.e., May 27, 1997 through June 23, 1997) and the 20 trading days including and after (i.e., June 24, 1997 through July 22, 1997) the change in price quoting. These data were obtained from the NYSE's TAQ database.

The TAQ trade and quote data are separate files. In merging the two data sets, we adopted the following procedures. For each trade of each stock each day, we obtained the most recent bid/ask prices quotes and market depth figures and append them to the trade record. The trade record itself contains the time of trade, the trade price, and the volume of shares traded. Since the first trade of the day is usually determined through a call auction market, it does not have supporting bid/ask price quotes. We drop these opening trades because we are interested only in determining the effects of the change in tick size on the bid/ask spread and other aspects of market microstructure. Consequently, if a stock traded only at the open on a particular day, it is not included in the analysis on that day.

Four exclusionary criteria are applied to the stocks in the sample. First, the shares of Berkshire Hathaway (A and B) are excluded because their share prices are so high (and spreads so large) that they are meaningless with respect to the issue at hand. Second, any stock with a stock split during the interval is excluded. Due to the discreteness of prices, the effects of stock

splits on the bid/ask spread are not well understood.[5] This eliminates 81 additional stocks. Third, any stock trading in ticks below $1/8^{th}$ prior to June 24, 1997 are eliminated. There are 27 such occurrences. Finally, any stock with no recorded trading volume in the 20 days before or the 20 trading days after the change in price reporting is eliminated. This restriction removes 33 stocks. The total number of stocks in our final sample is therefore 2,709.

From the data in the combined trade and quote file, we computed a number of measures of market activity and bid/ask spreads for each stock each day. Two measures of the quoted spread require definition:

> **Percentage quoted spread:** the average of the ratio of the quoted bid/ask spread to the bid/ask price midpoint; and,
>
> **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.

We measure the percentage quoted spread to illustrate that spreads differ by the level of share price.[6] Trading costs for low price per share stocks are higher. The volume-weighted quoted spread weights the prevailing quotes by the number of shares traded (as a proportion of total daily trading volume) while the quotes were in effect. Consequently, this measure of quoted spread is more accurate *a priori* since transactions at the prevailing quotes indicate that prices were "firm."

Our measures of market depth and market quality also merit comment. We attempt to measure market quality with an index that is designed to capture the tradeoff between quoted bid/ask spread and market depth. The market quality index (MQI) is the ratio of the average share depth at the prevailing bid and ask price quotes to the percentage quoted spread, that is,

$$\text{MQI} = \frac{(\textit{depth at bid} + \textit{depth at ask})/2}{\textit{percent spread}}, \tag{1}$$

where *depth at bid* and *depth at ask* are measured in thousands of shares and *percent spread* is the quoted bid/ask spread divided by the bid/ask price midpoint. To illustrate how this market

[5] For an examination of the effects of stocks splits on market maker spreads, see Gray, Smith and Whaley (1996).

[6] For a detailed investigation of the effects of transaction costs on the cross-sectional structure of stock returns, see Stoll and Whaley (1983).

quality index works, suppose that before the change to price quotes in 1/16ths the bid and ask price quotes are 49.875 and 50.125, respectively, with a depth of 1,000 shares on each side of the market. The pre-change MQI is

$$\text{MQI} = \frac{(1+1)/2}{\left[100\left(\frac{0.25}{(49.875+50.125)/2}\right)\right]} = 2.0 \tag{2}$$

Now, suppose that after the change to 1/16ths, the spread narrows from a quarter to 1/8th but the market depth falls to 500 on each side of the market. The post-change MQI is

$$\text{MQI} = \frac{(0.5+0.5)/2}{\left[100\left(\frac{0.125}{(49.9375+50.0625)/2}\right)\right]} = 2.0 \tag{3}$$

reflecting no change in the quality of the market. In other words, although the quoted spread has been reduced, the market depth has been reduced commensurately with no change in market quality. On the other hand, if the market depth remained at 1,000 shares on each side of the market, the MQI would double.

A large portion of trading volume takes place within the quoted bid/ask spread.[7] We document this behavior by measuring the proportion of daily trades (and the proportion of daily dollar volume) executed within the prevailing bid/ask price quotes. To account for the fact that trades take place within the prevailing quotes, we measure the "effective" spread as twice the absolute difference between the trade price and the midpoint of the quoted bid/ask spread, that is,

$$\text{Effective spread}_t = 2\left|\text{trade price}_t - \frac{(\text{bid price}_t + \text{ask price}_t)}{2}\right|. \tag{4}$$

Note that the effective spread measured in this way will always be less than the quoted spread. We also measure the volume-weighted effective spread for the same reason as we measure the volume-weighted quoted spread.

[7] 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.

II. Empirical Evidence in Aggregate

The basic framework of our analysis is to compare measures of trading volume, bid/ask spreads, market depth, and market quality in the 20 trading days prior to the switch to 1/16ths with those same measures in the 20 trading days after the switch. The measures outlined in the last section are computed for each stock each day. Each daily measurement for each stock is then averaged across the 20 days prior to the switch and after the switch. The averages are then aggregated across stocks to estimate market-wide changes in the microstructure measures. The change in the cross-sectional averages is tested using a t-test for a difference in means.[8]

In terms of market behavior during the investigation period, Figure 1 shows that the level of the NYSE Composite Index increased from a level of about 440 to 485 from the beginning of the pre-implementation period to the end of the post-period. This market-wide increase in price will affect some of our microstructure measures; percentage spread, for example, will fall if prices rise and spreads are constant. So we need to interpret some of our results with caution. Daily trading volume in shares varied from day to day and also showed a modest increase on average. This market-wide increase in trading volume will also affect some of our measures. We might expect market makers to increase their quoted depth in a more liquid trading environment, for example.

A. Microstructure measures

Panel A of Table 1 reports average trading activity. The average number of trades per day increased from 65.47 trades per day before the switch to 75.74 trades afterward—an increase of 15.69 percent.[9] Similarly, the average number of shares traded each day increased by 5.86 percent, while the average dollar trading volume increased by 11.97 percent. The difference

[8] A sign test and Wilcoxon signed rank test were also conducted for each measure to check robustness of the *t*-test. The results were identical and are omitted for the sake of brevity.

[9] We do not test for statistical significance here, in that we do not compare changes in the microstructure measures to their time-series standard deviation, since we are simply illustrating changes in the trading environment around the switch to 1/16ths. For changes in spread, depth, and market quality, we control for other factors in section II.B using a regression framework. The regression analysis statistically tests for a significant effect resulting from the switch to 1/16ths. The results confirm those listed here.

between the percentage increases in share volume versus dollar volume indicates that volume increased more for high-priced stocks than low-priced stocks—an issue that we return to later.

Interestingly, average trade size decreased after the change to 1/16ths. The average trade size fell by 9.33 percent when measured in number of shares and by 7.00 percent when measured in dollar volume. On one hand, this change could be as a result of smaller investors entering the market. On the other, large traders may be choosing to use a greater number of smaller orders so as not to exceed the depth at the prevailing bid/ask quotes.

Panel B of Table 1 reports measures of the quoted bid/ask spread. All measures decreased after the reduction in tick size. The average and median dollar quoted spreads, for example, fell by 14.54 percent. The number of stocks experiencing a drop in the average dollar quoted spread was 2,325 out of a total of 2,709 or 85.8 percent. The average percentage spread fell by 21.26 percent, considerably more than the average dollar spread. This implies that the quoted bid/ask spread as a proportion of share price fell more for low-priced shares than high-priced shares. We examine this relation more closely in Section IV. The volume-weighted average quoted spread fell by 13.32 percent, slightly less than the decrease in the average dollar spread. This means that higher volume stocks did not experience as great of reduction as did low volume stocks.

Figure 2 illustrates the empirical distribution of average quoted spread before and after the reduction in tick size. Note that a significant portion of the spreads of NYSE stocks dropped below 1/8th after the switch to 1/16ths, indicating that the tick size was indeed a constraint on many quoted spreads.

Panel C of Table 1 reports measures of market depth and market quality at the prevailing bid/ask quotes. The average number of shares at the bid was 11,703 prior to the NYSE's reduction in tick size and 7,429 afterward. In other words, the market depth in number of shares at the bid was reduced by 36.52 percent. The reduction in the market depth at the ask was slightly larger at 39.43 percent. The significance of the reduction in bid (ask) market depth is also reflected by the fact that 2,146 (2,130) out of 2,709 or about 79 percent of the stocks in the sample experienced a reduction. The percentage reductions in dollar depth were slightly smaller than share depth. Again, this is evidence that the change in tick size has affected low-priced shares and high-priced shares differentially.

The results in Table 1 provide strong evidence that both quoted bid/ask spreads and quoted market depth decreased significantly following the switch from quoting stock prices in 1/8ths to 1/16ths.[10] Figure 3 illustrates the sharp decline by plotting the daily average percentage spread and average share depth for the NYSE sample for the 20 trading days prior to the switch and the 20 trading days after and including June 24, 1997. A critical question is whether the investors' apparent savings from the reduction in bid/ask spreads has been offset by an inability to execute trades "in size." We attempt to answer this question using the Market Quality Index (MQI). As listed in Panel C of Table 1, after the NYSE's change in tick size, the market quality index rose only slightly, by an average of 1.44 percent. The number of stocks for which the market quality index increased totaled 1,424 or about 53 percent of the sample, not significantly different than what we would expect under the null hypothesis of no change. As measured by the MQI, the change to 1/16ths appears to have had little overall effect. A problem with this measurement is, of course, that it presumes all trades occur at the prevailing bid/ask price quotes.

Panel D of Table 1 shows a considerable percentage of daily trades are consummated within the prevailing bid/ask quotes—23.08 percent prior to the NYSE's change in tick size. After the change, the frequency has increased to 29.08 percent. Apparently, the move to a smaller price gradation has created more opportunities to negotiate trade prices within the spread.

The effective bid/ask spread measure accounts for trades within the quoted levels. The effective bid/ask spread is reduced by 13.13 percent on average, and 8.77 percent when weighted by volume. The volume-weighted average is probably more important in the sense that it measures the actual cost being incurred by investors. The difference between the two measures reflects the fact that the reduction in spread has been larger for less active stocks than more active stocks.

B. Robustness Tests

The evidence reported in Table 1 shows that the introduction of 1/16ths coincided with changes in the nature of trading and trading costs. In particular, trading costs have decreased

[10] This is consistent with the results of Bacidore (1997), who finds that over 91 percent of cross-listed stocks with a price greater than $5 (Cdn) on the Toronto Stock Exchange experienced a drop in quoted depth following its move

significantly and trading volumes have increased. Since changes in the bid/ask spread are the focus of much of the debate surrounding a change in the tick size, we need to determine whether the reduction in the spread is attributable to the change in the tick size and not attributable to changes in trading volume, volatility, and market competition.

To control for these other factors, we perform a set of time series regressions for each stock in the sample. Theoretical models of the quoted bid/ask spread, e.g. Stoll (1978), predict that spreads are determined by, among other factors, trading volume and price volatility. The higher is the trading volume, the greater is the market makers' time rate of transaction, and the lower is the margin that they need to cover the fixed cost of operation. Spreads should also vary with price risk. The greater is the price variability of a stock, the greater is the likelihood that an adverse price move occurs while the stock is in the market maker's inventory. The higher is the price risk, therefore, the higher is the spread. The regression model also includes a measure of the inter-market competition for the stocks. This is simply the number of exchanges that make a market in the stock. Ideally, intra-market competition should also be included. Unfortunately, there is no good way to measure the number of market makers standing ready to trade at each specialist's post. Finally, the regression includes an indicator variable to measure the shift in dependent variable over time after controlling for changes in the other independent variables.

The form of the regression is

$$X_{i,t} = a_0 + a_1 \mathrm{I}_t + a_2 \mathrm{Volume}_{i,t} + a_3 \mathrm{Volatility}_{i,t} + a_4 \mathrm{MktComp}_{i,t} + \varepsilon_t \qquad (5)$$

where

$X_{i,t}$ = dependent variable measured for stock i on day t (volume-weighted quoted spread, average market depth, market quality index, and volume-weighted effective spread);

I_t = an indicator variable which equals zero prior to June 24, 1997 and one thereafter;

$\mathrm{Volume}_{i,t}$ = trading volume of stock i on day t measured in thousands of shares;

$\mathrm{Volatility}_{i,t}$ = price change volatility measured as the difference between the high and low price midpoints of stock i on day t; and,

$\mathrm{MktComp}_{i,t}$ = number of exchanges making a market in stock i on day t.

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to share price decimalization.

The market competition variable is omitted if the number of exchanges did not change for a particular stock over the event window. The regression is performed for each stock. The results are summarized in Table 2 by the significance of the coefficient estimates. The coefficient, a_1, is key to the analysis in that it measures the effect of the NYSE's change in price quoting after controlling for the effects of other factors.

Overall, the results of Table 2 indicate that the effects reported in Table 1 are largely driven by the change in the tick size. Panel A of Table 2, for example, shows that, when the volume-weighted quoted spread is used as the dependent variable, 2,318 of the 2,703 coefficient estimates of a_1 are negative. This exceeds the 2,265 reductions reported in Panel B of Table 1. In other words, after controlling for other effects on the quoted spread, the reduction in spread as a result of the change in price quoting is more prevalent than it was before. Of the quoted spread's determinants, the strongest appears to be price volatility. The volatility coefficient a_3 is significantly positive for 718 stocks in the sample of 2,702.

When average market depth in shares is used as the dependent variable, the regression results are qualitatively similar to those of the quoted spread. The frequency of depth reductions, 2,201 of 2,703, is greater than it was in Table 1. Market depth is reduced significantly for 1,291 of the stocks in the sample. The risk variable again enters significantly for a large number of stocks. But, here the effect is negative, as expected. The greater is the price variability, the lower is the number of shares that the market maker is willing to trade at the prevailing quotes.

The market quality regression results reported in Panel C, like the results reported in Table 1, indicate that the change to $1/16^{th}$s had little effect. Seventy percent of the coefficient estimates are insignificantly different from zero, with the remaining 30 percent about evenly balanced between significant increases and significant decreases. The only economic variable with a notable impact on market quality appears to be price risk. The greater the price variability, the lower the market quality.

Finally, the volume-weighted effective spread regression results reported in Panel D of Table 2 indicate that spreads have decreased for 1,926 of the 2,703 stocks in the regression. This number is greater than it was in Table 1, indicating that once the effects of other factors are

eliminated, the impact of the change to 1/16ths is greater. The volume-weighted effective spread appears to be positively associated with price risk.

In summary, the robustness tests indicate that the sharp changes documented in trading behaviors in Table 1 are not attributable to fundamental economic factors but rather are attributable to the change in price quoting on the NYSE. The switch to 1/16ths has reduced trading costs for investors. In the short run, at least, investors are better off.[11] In the next section, we compute our market microstructure measures by share price quintile and trade size quintile in order to determine whether different stocks and trades were impacted differentially by the switch to 1/16ths. If different groups of investors can be characterized by the price of the stocks they trade and the amount in which they trade, then the stratified results will also determine how investors are affected differentially.

III. Stratified Results

To examine how the move to 1/16ths has impacted stocks differentially, we stratified the stocks in the sample by the average closing share price midpoint and average trade size in the 20 trading days leading up to June 24th, 1997. We then computed summary statistics for the key market measures by quintile.

A. Share Price Quintiles

Table 3 contains the results from the lowest price shares to the highest price shares. The low-price quintile has an average price of $8.10 whereas the high-price quintile has an average price of $61.42.

Panel B shows the quoted bid/ask spread for each share price quintile. The quoted bid/ask spread fell considerably in all share price quintiles; however, the largest reduction was for the low-priced share quintile, which experienced a 23.35 percent reduction. At the same time, there is a large reduction in market depth. Panel C shows that all share price quintiles experienced reductions in market depth measured in shares of at least 34 percent. The reductions are fairly uniform across quintiles, with the exception of Quintile 2.

[11] The long run implications are less clear, for some market makers may leave the market as a result of narrower spreads.

The Market Quality Index attempts to capture the tradeoff between the reduced quoted bid/ask spread and the reduced market depth. Panel D of Table 3 reveals the market quality index increased significantly for only low-priced shares. The improvement was 10.89 percent. The second lowest price quintile appears to have a large reduction in market quality, albeit insignificant in a statistical sense. The other quintiles' results are all small and statistically insignificant. The improvement in market quality for high-priced shares, for example, is less than one percent.

Interestingly, the reduction in tick size has not only reduced the size of the quoted bid/ask spread for low-priced shares but it has also increased the frequency with which trades occur within the prevailing spread. Panel E of Table 3 shows that the percentage of the dollar value of all trades during the day occurring at prices within the prevailing quotes has increased 31.74 percent for low-priced shares. These increases occur across the board for all share price quintiles, decreasing monotonically as share price increases. So, low-priced shares appear to have been doubly blessed. First, the minimum price change of $1/8^{th}$ prior to the change appears to have been binding on the quoted spread, so the quoted spread has now been reduced. Second, the refined price gradation has increased the frequency with which low-priced shares are traded at prices within the prevailing quotes.

Both of these effects are incorporated within the volume-weighted effective spread, as was described in greater detail earlier. So, the results in Panel F should not be surprising. The volume-weighted effective spread fell by 26.71 percent for the low priced share quintile, well in excess of all other quintiles. The effective spread reduction is 11.83 percent for the second lowest price quintile, 6.90 percent for the third quintile, and 6.36 percent for the fourth. The high-price quintile experiences an increase in the volume-weighted effective spread, albeit insignificant in a statistical sense. These results are illustrated graphically in Figure 4.

B. Trade Size Quintiles

To examine how the move to $1/16^{th}$s has impacted investors differentially, we also stratified the stocks in the sample by the average dollar trade size in the 20 trading days leading up to June 24^{th}, 1997 and computed the same summary statistics as in Table 3. Panel A of Table

4 indicates that the average trade size in the smallest trade size quintile was $12,399, and the average trade size in the largest trade size quintile was $110,598.

Panel B shows the quoted bid/ask spread fell considerably for all trade sizes. The small trade quintile, for example, has a 13.23 percent decrease, and the large trade quintile has a 14.61 percent decrease. Similarly, market depth has also fallen. Panel C shows a 34.67 percent reduction for the small trade quintile and a 43.08 percent reduction for the large trade quintile. Combining the two effects, the market quality results reported in Panel D show that the greatest beneficiaries are investors with small trades. The market quality index rose by 7.80 percent for small trades, and by about 5 percent for all other trade size quintiles, except the largest. The large trade size quintile experienced a 5.29 percent decline in market quality.

The proportion of the dollar value of trades within the quoted spread has its greatest increase for the small trade quintile, as is reported in Panel E of Table 4. Apparently, the market maker's increased flexibility in negotiating price has benefited investors with small trades. The positive benefits associated with small trades is also reflected in the volume-weighted effective spread figures reported in Panel F. The small trade quintile experienced an 11.54 percent drop, followed closely by an 11.49 percent drop for the second smallest quintile. For larger trades, the drop in not quite as large, albeit significant in a statistical sense.

There are two interpretations of these results. The first is that small investors, whose trades are small due to limited capital, benefit the most from the change in tick size. However, recall that the average trade size fell after the change, as reported in Panel A of Table 1. Since it is unlikely that the change in tick size has attracted more small investors to trade, an alternative interpretation is that large investors are strategically decreasing their average trade size.

IV. NYSE Market Share

The NYSE's decision to reduce tick size must have been predicated, at least in part, on the reduction of the tick size on other exchanges. An interesting question in its own right, therefore, is whether or not the NYSE gained market share as a result of its actions. Recall that Panel A of Table 1 showed that trading volume has indeed increased on the NYSE after the switch to 1/16ths. The number of trades was up 16 percent, the number of shares traded was up 6 percent, and the market value of shares traded was up by 12 percent, all highly significant. Table

5 seeks to examine to what extent the switch to 1/16ths has attracted trading volume away from the other domestic stock exchanges.

The results in Table 5 indicate that the NYSE's decision to reduce the tick size gathered market share. For the full sample of 2,709 stocks, the NYSE market share increased significantly from 81.93 to 83.02 percent. The price quintile results show that the gains are across the board, however, the gains are again largest for the lowest-priced shares.

V. Summary and Conclusions

This study examined the effects of the NYSE's decision to reduce the tick size of common stock price reporting from 1/8ths to 1/16ths. In analyzing 2,709 common stocks traded on the NYSE in the days surrounding the switch in price reporting on June 24, 1997, we find that spreads decreased significantly. Using cross-sectional daily averages over a 40-trading day window centered on June 24, 1997, we find that the volume-weighted quoted bid/ask spread has fallen by more than 13 percent. Along with the reduction in the quoted spread size came a reduction in the depth of the market at the prevailing bid/ask quotes. Quoted market depth expressed in shares dropped by about 38 percent following the switch. To distinguish between the two offsetting effects, we use, among other things, a measure of market quality that trades off between reduced quoted spreads and reduced market depth. Over the sample period, the market quality index increases by a modest 1.44 percent, indicating little change. Many trades take place within the prevailing quotes, however, and these trades are ignored when quoted measures are used. Using a measure of spread that accounts for trades executed within the quoted spread (i.e., the "volume-weighted effective spread"), we find that the spreads have been reduced by nearly 9 percent.

We also analyzed data stratified by price per share and by dollar trade size. The evidence shows clearly that low-priced stocks have gained the most. Indeed, the gains realized by high-price stocks may be regarded as marginal. This evidence may support the notion of an optimal tick size. Where shares have high prices, it is unlikely that price quoting in 1/8ths represented a binding constraint on the minimum size of the bid/ask spread. Consequently, when the NYSE reduced the minimum tick size to 1/16th, spreads and trades were largely unaffected. On the other

hand, for low-priced shares, quoting prices in 1/8ths was a binding constraint, artificially holding spreads at levels higher than they would otherwise be under a competitive environment. The results using the trade size quintiles indicate that investors with small trades have also benefited from the change in price quoting. Smaller dollar value trades experienced greater reductions in the effective bid/ask spread—in excess of 11 percent. These reductions appear to have had the desired effect, in the short-run at least, since the NYSE market share appears to have increased.

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Table 1

Average daily measures of the trading activity, trade size, quoted bid/ask spreads, market depth, market quality, and effective bid/ask spreads for a sample of 2,709 NYSE common stocks in the 20 trading days before (*Pre*) and the 20 trading days including and after (*Post*) the NYSE's implementation of price quoting in 1/16ths on June 24, 1997. Also listed are the difference between *Pre* and *Post* averages, the percentage difference, the number of negative differences (out of the total of 2,709), and the *p*-value of a *t*-test of the difference between means.

Panel A: Trading activity

	No. of trades	*Trading volume in shares*	*Trading volume in dollars*	*Trade size in shares*	*Trade size in dollars*	*Share price*
Pre	65.47	161,681	6,649,559	1,979.95	51,985.52	28.14
Post	75.74	171,159	7,445,273	1,795.19	48,344.03	29.31
Difference	10.27	9,478	795,715	-184.76	-3,641.49	1.16
% difference	15.69%	5.86%	11.97%	-9.33%	-7.00%	4.14%
No. of negatives	767	1,197	1,103	1,613	1,489	587
p-value (*t*-test)	0.000	0.001	0.000	0.000	0.000	0.000

Panel B: Quoted bid/ask spreads

	Average	*Median*	*Percentage*	*Volume-weighted average*
Pre	0.190	0.177	1.08%	0.193
Post	0.162	0.151	0.85%	0.168
Difference	-0.028	-0.026	-0.23%	-0.026
% difference	-14.51%	-14.54%	-21.26%	-13.32%
No. of negatives	2,325	2,234	2,426	2,265
p-value (*t*-test)	0.000	0.000	0.000	0.000

Panel C: Market depth and market quality

	No. of shares at bid	*No. of shares at ask*	*Dollar value at bid*	*Dollar value at ask*	*Market quality index*
Pre	11,703	11,951	209,471	227,109	152.15
Post	7,429	7,240	138,680	144,912	154.34
Difference	-4,274	-4,712	-70,791	-82,196	2.19
% difference	-36.52%	-39.43%	-33.80%	-36.19%	1.44%
No. of negatives	2,146	2,130	2,074	2,069	1,285
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.353

Panel D: Effective Spreads

	Percentage of trades within spread	*Percentage of dollar value within spread*	*Effective spread Average*	*Effective spread Volume-weighted average*
Pre	23.08%	21.42%	0.129	0.140
Post	29.08%	24.34%	0.112	0.127
Difference	6.01%	2.92%	-0.017	-0.012
% difference	26.03%	13.64%	-13.13%	-8.77%
No. of negatives	476	886	2,131	1,911
p-value (*t*-test)	0.000	0.000	0.000	0.000

Table 2

Summary of coefficient estimate significance in daily time-series regressions of a stock's volume-weighted quoted spread (VWQS), average market depth (AMD), market quality index (MQI), and volume-weighted effective spread (VWES) on dummy variable for the 20 trading days before (*Pre*) and the 20 trading days including and after (*Post*) the NYSE's implementation of price quoting in 1/16ths on June 24, 1997, daily trading volume in shares, risk as measured by the high/low range, and number of competing exchanges. To be included in this analysis, a stock had to have at least two daily observations in each of the *Pre* and *Post* periods. Where a particular variable had no variation over the time series, it was not included in the regression estimation.

$$X_{i,t} = a_0 + a_1 \mathrm{I}_t + a_2 \mathrm{Volume}_{i,t} + a_3 \mathrm{Volatility}_{i,t} + a_4 \mathrm{MktComp}_{i,t} + \varepsilon_t,$$
$$\text{where } X_{i,t} = \mathrm{VWQS}_{i,t},\ \mathrm{AMD}_{i,t},\ \mathrm{MQI}_{i,t}, \text{ and } \mathrm{VWES}_{i,t}.$$

	Number of estimates					
Coefficient	*Total*	*Negative*	*Significantly negative*	*Insignificant*	*Significantly positive*	*Average*
Panel A: Volume-weighted quoted spread (VWQS)						
Adjusted R^2						0.3277
a_0	2,703	6	0	150	2,553	
a_1	2,703	2,318	1,560	1,101	42	
a_2	2,703	1,043	75	2,367	261	
a_3	2,702	403	8	1,976	718	
a_4	2,580	1,656	166	2,388	26	
Panel B: Average market depth in shares (AMD)						
Adjusted R^2						0.2116
a_0	2,703	128	2	991	1,710	
a_1	2,703	2,201	1,291	1,332	80	
a_2	2,703	1,163	66	2,444	193	
a_3	2,702	2,083	378	2,309	15	
a_4	2,580	1,060	60	2,402	118	
Panel C: Market quality index (MQI)						
Adjusted R^2						0.1260
a_0	2,703	252	5	1,399	1,299	
a_1	2,703	1,222	349	1,931	423	
a_2	2,703	1,415	125	2,413	165	
a_3	2,702	2,132	400	2,280	22	
a_4	2,580	958	39	2,394	147	
Panel D: Volume-weighted effective spread (VWES)						
Adjusted R^2						0.2292
a_0	2,703	59	2	592	2,109	
a_1	2,703	1,926	914	1,713	76	
a_2	2,703	1,845	245	2,405	53	
a_3	2,702	431	27	1,892	783	
a_4	2,580	1,385	96	2,428	56	

Table 3

Average daily measures of closing share price, volume-weighted quoted spread, average market depth, market quality, and volume-weighted effective spread arranged by stock price quintile for a sample of 2,709 NYSE common stocks in the 20 trading days before (*Pre*) and the 20 trading days including and after (*Post*) the NYSE's implementation of price quoting in 1/16ths on June 24, 1997. Also listed are the difference between *Pre* and *Post* averages, the percentage difference, the number of negative differences (out of the total of 2,709), and the *p*-value of a *t*-test of the difference between means.

Panel A: Average price

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
No. of observations	542	542	542	542	541
Average price	8.10	15.51	22.72	33.02	61.42

Panel B: Volume-weighted quoted spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	0.155	0.173	0.2	0.201	0.237
Post	0.119	0.15	0.176	0.176	0.216
Difference	-0.036	-0.024	-0.024	-0.025	-0.020
% difference	-23.35%	-13.60%	-12.02%	-12.29%	-8.51%
No. of negatives	487	431	447	451	449
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel C: Average market depth in shares

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	26,457	14,032	6,930	6,393	5,311
Post	16,707	8,031	4,371	4,165	3,390
Difference	-9,750	-6,002	-2,559	-2,228	-1,920
% difference	-36.85%	-42.77%	-36.93%	-34.85%	-36.16%
No. of negatives	453	448	407	414	447
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel D: Market quality index

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	162.57	153.88	107.84	142.66	193.87
Post	180.27	143.07	107.80	145.59	195.04
Difference	17.70	-10.81	-0.04	2.93	1.17
% difference	10.89%	-7.03%	-0.04%	2.05%	0.60%
No. of negatives	261	319	232	236	237
p-value (*t*-test)	0.000	0.124	0.993	0.535	0.814

Panel E: Percentage of dollar value within quoted spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	13.50%	18.21%	23.68%	24.73%	26.98%
Post	17.79%	22.30%	26.64%	26.70%	28.28%
Difference	4.29%	4.09%	2.96%	1.97%	1.30%
% difference	31.74%	22.45%	12.51%	7.96%	4.83%
No. of negatives	150	169	191	183	193
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel F: Volume-weighted effective spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	0.122	0.129	0.142	0.142	0.162
Post	0.092	0.114	0.132	0.133	0.166
Difference	-0.030	-0.015	-0.010	-0.009	0.003
% difference	-24.70%	-11.83%	-6.90%	-6.36%	1.91%
No. of negatives	463	387	358	370	333
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.431

Table 4

Average daily measures of closing share price, volume-weighted quoted spread, average market depth, market quality, and volume-weighted effective spread arranged by dollar trading volume quintile for a sample of 2,709 NYSE common stocks in the 20 trading days before (*Pre*) and the 20 trading days including and after (*Post*) the NYSE's implementation of price quoting in 1/16ths on June 24, 1997. Also listed are the difference between *Pre* and *Post* averages, the percentage difference, the number of negative differences (out of the total of 2,709), and the *p*-value of a *t*-test of the difference between means.

Panel A: Average trade size in dollars

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
No. of observations	542	542	542	542	541
Average trade size	12,399	22,536	35,792	60,509	110,598

Panel B: Volume-weighted quoted spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	0.192	0.187	0.194	0.201	0.192
Post	0.167	0.162	0.168	0.177	0.164
Difference	-0.025	-0.026	-0.025	-0.024	-0.028
% difference	-13.23%	-13.81%	-13.11%	-11.92%	-14.61%
No. of negatives	423	443	455	463	481
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel C: Average market depth in shares

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	11,436	17,443	11,802	7,413	11,040
Post	7,472	10,852	7,306	4,756	6,284
Difference	-3,965	-6,591	-4,496	-2,657	-4,756
% difference	-34.67%	-37.78%	-38.10%	-35.84%	-43.08%
No. of negatives	389	422	411	445	502
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel D: Market quality index

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	62.09	147.64	131.53	126.15	293.6
Post	66.93	154.86	139.41	132.64	278.08
Difference	4.84	7.22	7.88	6.48	-15.52
% difference	7.80%	4.89%	5.99%	5.14%	-5.29%
No. of negatives	255	261	239	225	305
p-value (*t*-test)	0.053	0.225	0.238	0.083	0.012

Panel E: Percentage of dollar value within quoted spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	19.48%	17.81%	21.56%	23.70%	24.55%
Post	24.08%	21.54%	23.87%	25.65%	26.58%
Difference	4.60%	3.73%	2.30%	1.95%	2.03%
% difference	23.61%	20.96%	10.68%	8.23%	8.25%
No. of negatives	167	160	192	201	166
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000

Panel F: Volume-weighted effective spread

Quintile	*Lowest*	*2*	*3*	*4*	*Highest*
Pre	0.141	0.137	0.141	0.144	0.136
Post	0.125	0.122	0.128	0.136	0.126
Difference	-0.016	-0.016	-0.012	-0.007	-0.010
% difference	-11.54%	-11.49%	-8.77%	-5.06%	-7.08%
No. of negatives	386	386	379	368	392
p-value (*t*-test)	0.000	0.000	0.000	0.001	0.000

Table 5

Average proportion of total daily trading volume (across eight U.S. stock markets) executed on the NYSE arranged by stock price quintile for a sample of 2,709 NYSE common stocks in the 20 trading days before (*Pre*) and the 20 trading days including and after (*Post*) the NYSE's implementation of price quoting in 1/16ths on June 24, 1997. Also listed are the difference between *Pre* and *Post* averages, the percentage difference, the number of negative differences (out of the total of 2,709), and the *p*-value of a *t*-test of the difference between means.

	NYSE market share					
	Full	*Price quintiles*				
	sample	*Lowest*	*2*	*3*	*4*	*Highest*
No. of observations	2,709	542	542	542	542	541
Pre	81.93%	71.89%	79.18%	83.56%	86.30%	88.72%
Post	83.02%	73.42%	80.33%	84.72%	87.31%	89.35%
Difference	1.09%	1.52%	1.15%	1.16%	1.02%	0.62%
% difference	1.34%	2.12%	1.45%	1.39%	1.18%	0.70%
No. of negatives	1,099	214	225	220	221	219
p-value (*t*-test)	0.000	0.000	0.000	0.000	0.000	0.001

Figure 1

NYSE Composite Index level and NYSE trading volume in thousands of shares in the 20 trading days before and the 20 trading days after the reduction in the minimum tick size from 1/8th to 1/16th on June 24, 1997.

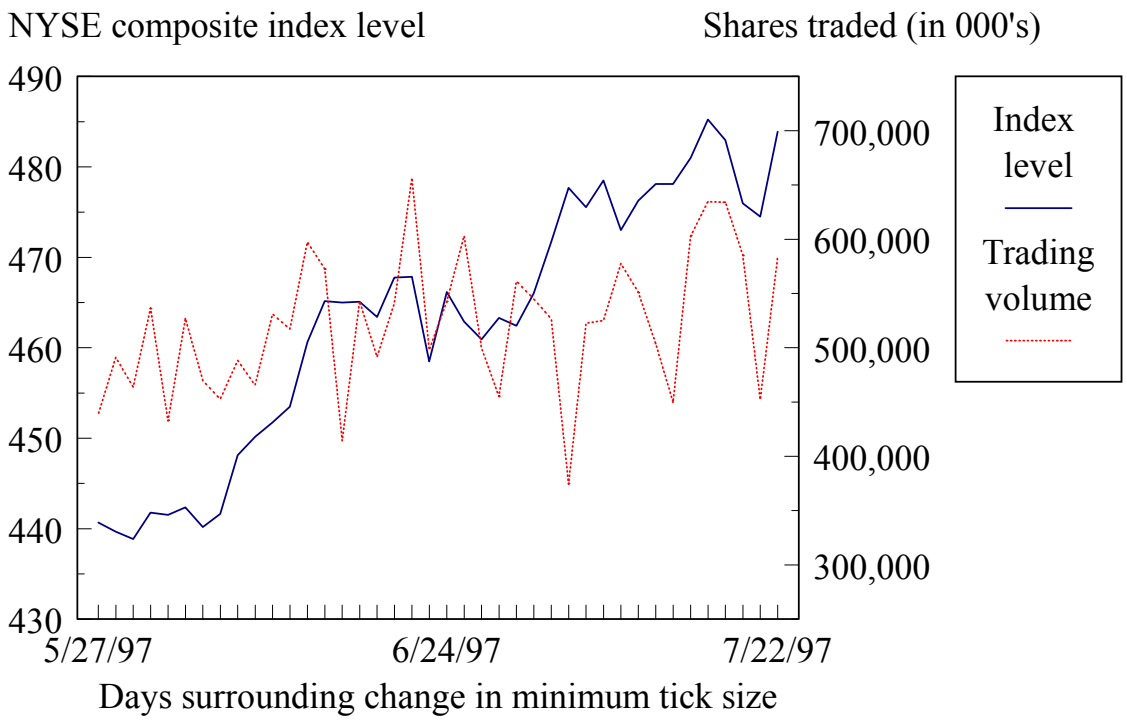

Figure 2

NYSE common stocks arranged by average quoted spread in the 20 trading days before and the 20 trading days after the reduction in the minimum tick size from 1/8th to 1/16th on June 24, 1997. Large outliers are not represented (41 stocks in the pre-period and 40 stocks in the post-period).

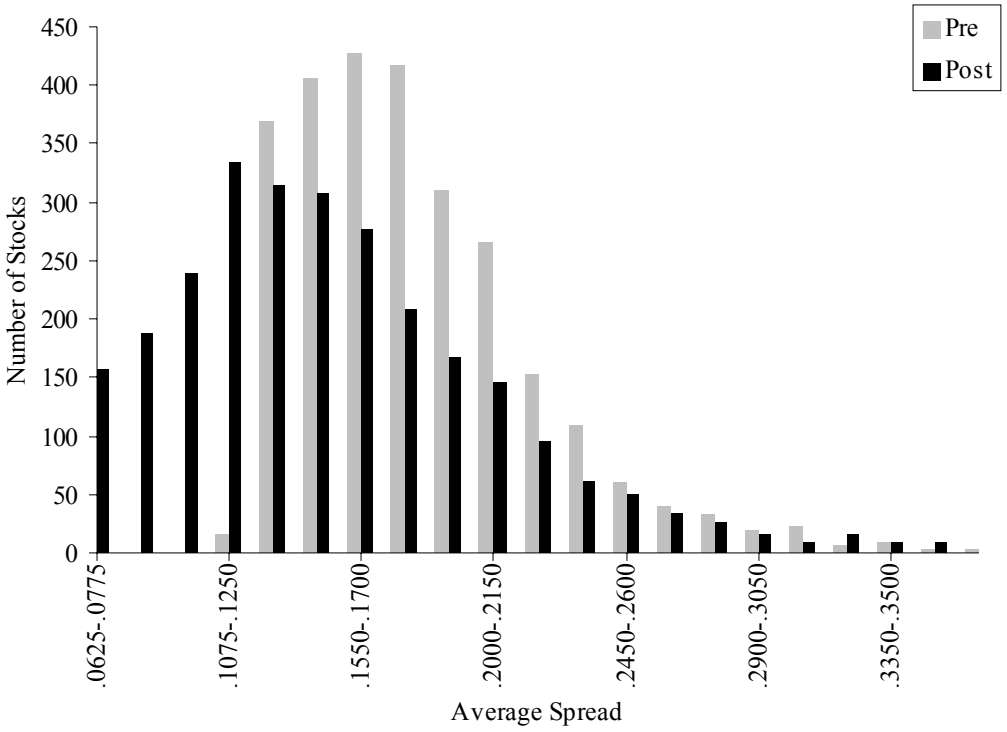

Figure 3

Average quoted bid/ask spread and average depth in shares of 2,709 NYSE common stocks in the 20 trading days before and the 20 trading days after the reduction in the minimum tick size from 1/8th to 1/16th on June 24, 1997.

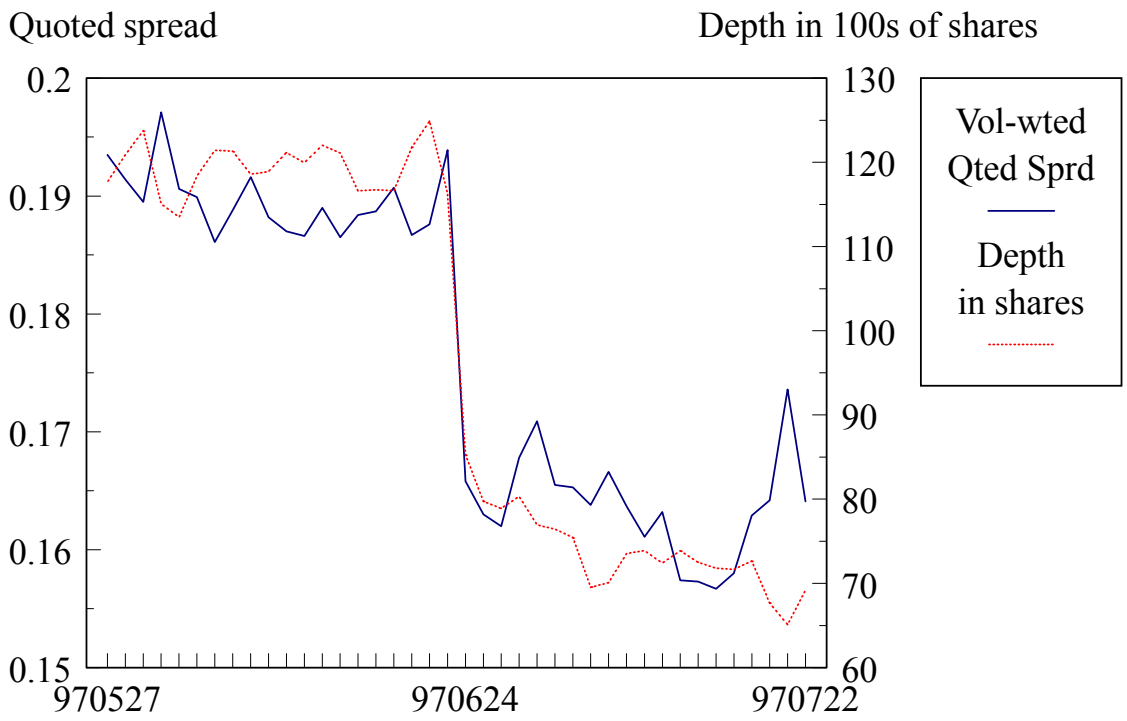

Figure 4

Average volume-weighted effective spread for 2,709 NYSE common stocks by share price quintile in the 20 trading days before and the 20 trading days after the reduction in the minimum tick size from 1/8th to 1/16th on June 24, 1997.