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Tick Size, Spread, and Volume

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The AMEX changed the tick size from $\$\frac{1}{8}$ to $\$\frac{1}{16}$ for low-price stocks on September 3, 1992. Consistent with the prediction of L. E. Harris (1994, Minimum price variations, discrete bid–ask spreads, and quotation sizes, *Rev. Finan. Stud.* **7,** 149–178), the change has reduced both quoted and effective spreads, although the magnitude of the reduction is much smaller than predicted. However, we fail to find evidence of a significant increase in trading volume. Our cross-sectional regressions show that stocks with greater trading activity, lower prices, and stronger competition from the regional exchanges experienced greater spread reductions. *Journal of Economic Literature* Classification Numbers: G10, G18, G20. © 1996 Academic Press, Inc.

1. INTRODUCTION

The American Stock Exchange (AMEX) reduced the minimum price variation (tick size) from $\$\frac{1}{8}$ to $\$\frac{1}{16}$ for stocks priced between \$1 and \$5 on September 3, 1992. We exploit this rare opportunity to investigate the effect of the reduction in the minimum price variation on bid–ask spread, trading volume, and market depth. Our investigation is important for two reasons. One, it is the first out-of-sample test of the Harris (1994) model. The Harris model provides a specific prediction regarding the impact of the reduction in the minimum price variation on bid–ask spread, trading volume, and market depth. Two, perhaps more importantly, it provides direct evidence useful in understanding the costs and benefits of changing the century-old $\$\frac{1}{8}$ fractional pricing system in the stock market. How exchange specialists and investors will respond to changes in the minimum spread size and to

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changes in the pricing system is central to the ongoing regulatory debate over fractional versus decimal pricing systems.[1] While there are numerous arguments regarding the consequences of changing the pricing system, none of them are based on empirical evidence.

This study focuses on transaction costs, trading volume, and market depth surrounding the change in the AMEX's tick-size rule. We use two different benchmark stock groups to test whether the changes in these variables are significant. The first benchmark group consists of the New York Stock Exchange (NYSE) stocks priced between \$1 and \$5, and the second contains the AMEX stocks priced between \$5 and \$10. These two benchmark groups enable us to control for the influence of other factors that are unrelated to the AMEX tick-size change.

Our main finding is that the AMEX tick-size change from $\$\frac{1}{8}$ to $\$\frac{1}{16}$ has a significant impact on the effective spread as well as on the quoted spread for stocks traded at prices between \$1 and \$5, although the impact is not uniform across stocks. The significant decrease in the spread is primarily due to an increase in one-sixteenth quotations and a decrease in one-eighth quotations. Trading activity (measured by daily share and dollar volume) and market depth (measured by quotation quantity), however, do not change significantly in response to this reduction in tick size.

This study is closely related to those of Ball *et al.* (1985) and Harris (1991, 1994). In particular, Harris (1994) develops a cross-sectional model for the discrete spread and uses the estimated model to predict the reduction in the spread, the change in $\$\frac{1}{16}$ quote frequency, trading volume, and market depth once the tick size is reduced from $\$\frac{1}{8}$ to $\$\frac{1}{16}$. For stocks with prices less than \$10, the model predicts a significant reduction in the bid–ask spread as well as in the quotation, but a significant increase in trading volume (Harris, 1994, p. 149). For actively traded stocks, we find that the direction of the changes in the spread and the spread frequency at $\$\frac{1}{16}$ are generally consistent with Harris' prediction, although the magnitudes of the changes are much smaller than predicted. For example, during the three-month period after the AMEX changed the rule, the quoted spread, as well as the effective spread, declined by about 19%. The effective spread decreased from 13.1 to 10.6 cents per share, suggesting a significant reduction in transaction costs paid by investors. The proportion of the spread quoted at $\$\frac{1}{16}$ increases from nothing to 28%, and the spread quoted at $\$\frac{1}{8}$ decreases from 72 to 51%.

However, there is no significant increase in trading volume attributed to

[1] Strictly speaking, the issue of fractional versus decimal pricing is not the same as the issue of reducing the minimum price variation. However, the debate over decimal pricing centers on the benefits and costs of reducing the minimum price variation. For example, see Securities and Exchange Commission (SEC) (1994).

the reduction in tick size. Our result also shows that the decreased tick-size rule does not have much impact on infrequently traded stocks. For these stocks, the effective spread, the frequency of the quote at $\$\frac{1}{8}$, the trading volume, and the quotation are almost unchanged.

Our cross-sectional regressions further reveal that stocks with greater trading activity, lower prices, and stronger competition from the regional exchanges experienced greater reductions in spreads. That is, these stocks are more likely to be bound by the $\$\frac{1}{8}$ tick size.

The remainder of this paper is organized as follows. Section 2 discusses the policy debate and develops testable hypotheses. Section 3 describes the data and outlines empirical tests. Section 4 presents the results, and Section 5 concludes.

2. EMPIRICAL ISSUES

A. *Fractional versus Decimal Pricing*

For most stocks traded on the NYSE and the AMEX, the minimum price variation is mandated by exchange rules to be $\$\frac{1}{8}$, which often coincides with the bid–ask spread.[2] Recently, this $\$\frac{1}{8}$ minimum price variation has come under attack by policy makers and investors. Some believe that the minimum price variation of $\$\frac{1}{8}$ may artificially inflate bid–ask spreads. They argue that the $\$\frac{1}{8}$ minimum price variation hinders competition among dealers and imposes unnecessary transaction costs on investors for several reasons: (1) For low-price stocks, the $\$\frac{1}{8}$ minimum price variation may be too large to accommodate typical changes in fundamentals, which in turn may make prices uninformative. (2) If one dealer offers his best bid–ask prices and another dealer can offer a narrower spread but the improvement is not $\$\frac{1}{8}$ or more, the second dealer will be prohibited from posting his bid–ask prices when the minimum variation is $\$\frac{1}{8}$. Consequently, investors pay more than necessary to execute a trade. (3) The minimum increment of $\$\frac{1}{8}$ in prices "may contribute to the practice of payment for order flow by ensuring a dealer's spread that is large enough for a market maker to pay profitably a penny or two a share for order flow" (SEC, 1994, p. 18). By executing a trade through a market maker or nonexchange dealer who posts a wider spread, brokers may benefit from receiving side payments at

[2] According to NYSE Rule 62, the minimum price variation for securities selling above $1 per share is $\$\frac{1}{8}$. AMEX Rule 127 imposed the same minimum price variation for stocks traded at or above $1 until September 2, 1992. The AMEX stocks that were previously traded on the National Association of Security Dealer Automated Quotation/National Market System (NASDAQ/NMS) and that had low prices could be traded on sixteenths before September, 1992.

the expense of investors because the trade is not executed at the best price. SEC (1994) concludes that the current pricing system with minimum variation of $\$\frac{1}{8}$ for the majority of stocks needs revision and "decimal pricing is preferable and may be inevitable at some point in the future."

Advocates of reduced price variation and decimal pricing argue that the reduction in tick size will lead to a decrease in transaction costs paid by investors and an increase in trading volume. It will also lead to an increase in profits for market markers and an improvement in market liquidity. Ultimately, a decimal trading system will make the U.S. exchanges more competitive in the global market. Moreover, the decimal trading system has already been adopted by many foreign exchanges. Opponents claim that the narrower spread may force market makers to abandon infrequently traded stocks, or to reduce their support for these stocks. As a result, market liquidity for these stocks would decrease, and thus impose additional costs on investors who wanted to trade them.

B. *Testable Hypotheses*

Bid–Ask Spread. Since the posted spread cannot be smaller than the tick size, the observed spread can be higher than the spread which would be quoted if a smaller price variation were permitted. Harris (1994) documents that the tick size of $\$\frac{1}{8}$ is binding for many stocks. According to his estimate, 45% of all NYSE quotations had a spread of $\$\frac{1}{8}$. If the tick size is an important constraint, a reduction in the minimum price variation will decrease the spread. Further, the decrease in the spread is expected to be greater for lower price stocks because the constraint is likely to be more binding for these stocks.

Trading Volume and Market Depth. Intuitively, the trading cost is negatively related to trading volume. Since a binding minimum price variation makes stock trading unnecessarily expensive by artificially inflating the spread, it forces investors to trade less than they otherwise would. Hence, a reduction in tick size is likely to increase trading volume. In addition to the impact on trading volume, the reduction in the tick size also makes the provision of liquidity less profitable. Thus, liquidity suppliers such as market makers are less willing to trade.[3] Furthermore, a smaller tick size will increase the probability of trading with informed traders.[4] Consequently, a reduction in tick size is likely to reduce the market depth.

Harris' Predictions. Harris (1994) estimates a discrete spread model for

[3] As Harris (1994) and Biais *et al.* (1994) point out, price discreteness and time priority create incentives to supply liquidity.

[4] Anshuman and Kalay (1993) argue that price discreteness reduces the value of private information.

the NYSE/AMEX stocks. Based on the estimation result, he provides detailed predictions on the expected changes in the spread, trading volume and market depth following a reduction in tick size. Specifically, the model predicts that the average spread will decrease by 38% (from 17 to 10.5 cents) for stocks priced below \$10 if the tick size is reduced from $\$\frac{1}{8}$ to $\$\frac{1}{16}$. It also predicts that daily trading volume will increase by 34% and market depth will decrease by 16%.

3. DATA

The intraday data used in this paper are from the 1992 Institute for the Study of Security Markets (ISSM) transactions file. We initially selected all common stocks listed on the NYSE or AMEX during the period from June to November 1992. Since the AMEX reduced the tick size from $\$\frac{1}{8}$ to $\$\frac{1}{16}$ for stocks priced between \$1 and \$5 on September 3, 1992, we chose a three-month period before this date and another three-month period after this date. The first period is from June 1 to August 31, 1992 (the pre-event period) and the second is from September 3 to November 30, 1992 (the post-event period). Several exclusion criteria are applied sequentially. First, a stock is dropped from the sample if it experiences a split or a reverse split at any time during the six-month sample period. Second, a stock is excluded if its average price is less than \$1 or greater than \$10 in either the pre-event or the post-event period. The average price is defined as the average daily closing price over the period. Third, the AMEX stocks traded on odd sixteenths before September 3, 1992 are also eliminated.[5] The AMEX permitted trading on sixteenths for low-price stocks that were previously traded on NASDAQ/NMS.

In each period, we divide the remaining stocks into two groups based on whether the average price is between \$1 and \$5, or between \$5 and \$10. If the price group of a stock in the post-event period is different from that in the pre-event period, the stock is excluded from the sample. This procedure ensures that the same number of stocks exists in both pre- and post-event periods and facilitates comparison between the two periods. The AMEX stocks in the \$1–\$5 price group will be the main sample (159 stocks) because stocks in this group are affected by the new tick-size rule. The remaining three groups, the AMEX stocks in the \$5–\$10 price group (145 stocks) and the NYSE stocks in the \$1–\$5 price group (125 stocks) and in the \$5–\$10 price group (252 stocks), are used as control samples.

We use several standard filters to screen the trade and quote data. Trades

[5] This criterion excludes 26 \$1–\$5 range and 4 \$5–\$10 range AMEX stocks from the sample. In an earlier version, we did not eliminate these stocks. The results were virtually the same.

flagged by the ISSM as errors as well as nonstandard delivery trades are eliminated. All quotes that are not BBO (Best Bid & Offer) eligible are also eliminated.[6]

If a trade/quote observation is recorded before 9:30 AM or after 4:04 PM,[7] the observation is discarded. Further, we exclude all quotes originating in markets other than the primary exchange because regional quotes tend to closely follow the quotes posted by the primary exchange. We exclude daily opening trades, which are made in a batch auction, from all analyses except for the analysis of trading volume.

4. EMPIRICAL RESULTS

To examine the impact and consequence of the AMEX tick-size change on various characteristics of trades and quotes (the quoted bid–ask spread, the effective spread, the trading volume, and the ask and bid quantities per quote), we adopt a uniform aggregation procedure. For a given variable of interest, we first calculate the average of the variable over the three-month period for each stock, and then obtain the cross-sectional mean, median, and standard error. When examining the change in the variable caused by the tick-size change, it is important to control for the effects of other confounding factors. For this purpose, we compare the change in the variable for the AMEX stocks in the price range of \$1–\$5 with those of two different control groups: (1) the NYSE stocks that are priced between \$1 and \$5, and (2) the AMEX stocks that are priced between \$5 and \$10. The first group is used to control for factors that affect trading characteristics of low-price stocks, and the second group is used to control for factors that affect stocks on the same exchange but in a different price range.

In addition to the above two tests, we conduct another test which is identical to the second test (i.e., comparing with the AMEX \$5–\$10 stocks), except that the variable is adjusted for the proportional difference between the two price-range groups.[8] The adjustment factor we use is the ratio of the average change for the NYSE \$1–\$5 stocks to the average change for the NYSE \$5–\$10 stocks. We adjust the variable for each stock in the AMEX \$5–\$10 price group by multiplying it by this adjustment factor. The resulting benchmark is potentially more informative because it may capture, over time, the systematic relationship between the \$1–\$5 and \$5–\$10 groups.

[6] BBO-ineligible quotes are closing quotations, trading halts, pre-opening indications, and nonfirm quotations.

[7] We use 4:04 instead of 4:00 p.m., following the ISSM's recommendation. See ISSM manual.

[8] We are grateful to an anonymous referee for suggesting this test.

TABLE I
SUMMARY STATISTICS OF THE SPREAD, TRADING VOLUME, AND MARKET DEPTH FOR THE AMEX $1–$5 STOCKS

	Quoted spread in cents	Effective spread in cents	No. of trades	Share volume in 100's	Dollar volume in $100's	Ask size per quote in 100's	Bid size per quote in 100's
Mean	18.41	14.18	5.82	94.05	328.25	34.60	39.60
Std. dev.	3.09	3.47	8.83	201.26	697.87	67.51	63.16
10th percentile	14.93	10.87	0.58	4.83	12.79	6.66	6.92
1st quartile	16.35	12.11	1.05	10.77	28.43	9.75	13.76
Median	18.00	13.45	2.88	26.57	86.82	17.09	22.18
3rd quartile	19.92	15.49	6.22	76.91	282.22	34.53	40.87
90th percentile	22.62	18.18	13.86	189.82	783.69	72.42	81.16

Note. The cross-sectional distributions for the average quoted spread, effective spread, daily number of trades, daily share volume, daily dollar volume, ask size, and bid size per quote are reported for the 159 AMEX stocks priced between $1 and $5. For a given stock, the averages are calculated from the three-month period prior to September 3, 1992, the day on which the new tick size rule became effective. The quoted spread is the difference between the ask and bid quotes. The effective spread is calculated as $2|p_t - q_t|$, where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t.

Two statistical tests are conducted. The first is the F-test and the second is the nonparametric Wilcoxon rank-sum test. We use both tests because they complement one another. While the F-test is more powerful under the normality assumption, the Wilcoxon test is more robust when the distribution of the test statistic is nonnormal. We test whether the ''change'' in the variable for the AMEX stocks in the $1–$5 price range differs from that of our benchmark groups. Table I provides the cross-sectional distributions of the variables analyzed. The following subsections report empirical results.

A. *The Bid–Ask Spread*

Table II reports descriptive statistics for the quoted spread (in cents) and the percentage change in the quoted spread for the AMEX and the NYSE stocks. The quoted spread is calculated as the difference between the ask and bid quotes. For the AMEX stocks in the $1–$5 price range, Table II (Panel A) shows that the mean quoted spread indeed declines after the AMEX reduced the tick size. The average spreads are 18.4 and 16.7 cents for the pre- and post-event periods, respectively. The reduction in the spread is about 1.7 cents, or 9.6%. The spreads for the two benchmark groups ($5–$10 AMEX stocks and $1–$5 NYSE stocks) remain unchanged in the post-event period (Panels A and B, Table II). Furthermore, all test

TABLE II
THE QUOTED SPREAD (IN CENTS) FOR THE AMEX AND NYSE STOCKS

	A. AMEX stocks					
	\$1–\$5 (N = 159)			\$5–\$10 (N = 145)		
	Before	After	Change (%)	Before	After	Change (%)
Mean	18.41	16.70	−9.61	20.40	20.41	0.27
(S.E.)	(0.24)	(0.30)	(1.16)	(0.33)	(0.35)	(0.71)
Median	18.00	17.05	−7.50	20.28	20.24	0.23
	B. NYSE stocks					
	\$1–\$5 (N = 125)			\$5–\$10 (N = 252)		
	Before	After	Change (%)	Before	After	Change (%)
Mean	17.49	17.13	−1.25	17.82	17.80	0.42
(S.E.)	(0.26)	(0.21)	(0.83)	(0.24)	(0.22)	(0.48)
Median	16.91	16.86	−1.45	17.69	17.54	−0.42

Note. The quoted spread and percentage change in the quoted spread are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick-size rule became effective. The quoted spread is the difference between the ask and bid quotes.

statistics strongly reject the null hypotheses that there is no difference in the percentage change of the spread between the AMEX \$1–\$5 group and the three benchmark groups. The evidence suggests that the reduction in the spread is statistically significant.

While the significant reduction in the mean spread is consistent with Harris' prediction, the observed magnitude of the reduction is short of his prediction. Since many stocks listed on the AMEX are traded infrequently, the cross-sectional average spread may not represent the average transaction costs because each stock is weighted equally regardless of its trading frequency. To examine the impact of the minimum tick rule change on stocks with different trading frequency, we partition the \$1–\$5 AMEX stocks into three equal-sized subsamples based on the average number of daily trades. Since the reduction in tick size may affect the trading frequency, using the trading frequency in the post-event period as an exogenous classification variable is questionable. To avoid the endogeneity problem, we use the trading frequency during the pre-event period.

In Table III, we report summary statistics for the quoted spread for the AMEX stocks (\$1–\$5) in three categories. In both pre- and post-event periods, the bid–ask spread is inversely related to the number of trades. For example, for the least actively traded, the middle, and the most actively traded groups, the average spreads per share are 20.6, 18.4, and 16.2 cents,

TABLE III
THE QUOTED SPREAD (IN CENTS) FOR THE AMEX STOCKS SORTED BY TRADING FREQUENCY ($1–$5 PRICE GROUP)

A. Summary statistics

	No. of trades ≤ 1.65 (N = 53)			1.65 < No. of trades ≤ 4.90 (N = 53)			4.90 < No. of trades (N = 53)		
	Before	After	Change (%)	Before	After	Change (%)	Before	After	Change (%)
Mean	20.62	19.50	−4.29	18.44	17.34	−5.78	16.19	13.25	−18.74
(S.E.)	(0.48)	(0.40)	(1.90)	(0.20)	(0.27)	(1.31)	(0.30)	(0.45)	(2.12)
Median	20.31	19.60	−4.37	18.48	17.46	−6.00	15.91	13.36	−20.01

B. Tests of the null hypothesis that there is no difference in percentage changes between the AMEX $1–$5 group and each of the three benchmark groups; p values are reported

	No. of trades ≤ 1.65		1.65 < No. of trades ≤ 4.90		4.90 < No. of trades	
Benchmark Group	F-test	Wilcoxon test	F-test	Wilcoxon test	F-test	Wilcoxon test
AMEX $5–$10 stocks	0.006	0.001	0.000	0.000	0.000	0.000
AMEX $5–$10 stocks (adjusted)[a]	0.078	0.016	0.002	0.002	0.000	0.000
NYSE $1–$5 stocks	0.088	0.007	0.004	0.001	0.000	0.000

Note. The quoted spread and percentage change in the quoted spread are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. All stocks in the sample are partitioned into three groups based on average daily number of trades in the pre-event period. The quoted spread is the difference between the ask and bid quotes.

[a] For each stock, the adjustment factor is

$$\left[\frac{\text{cross-sectional mean \% change for NYSE \$1–\$5 group}}{\text{cross-sectional mean \% change for NYSE \$5–\$10 group}}\right].$$

respectively. Surprisingly, the reduction in the quoted spread in response to the tick-size change is positively related to the trading frequency. While the least frequently traded stocks exhibit a 4% decrease in the quoted spread (from 20.6 to 19.5 cents), the most actively traded stocks show a 19% reduction in the spread (from 16.2 to 13.3 cents). This positive relationship may be related to the components of the bid–ask spread. Glosten and Harris (1988), Stoll (1989), George *et al.* (1991), Madhavan *et al.* (1994), Huang and Stoll (1994), and many others decompose the bid–ask spread into the order processing component and the asymmetric information cost component.[9] The major component of the spread is the order processing

[9] A third component is the inventory cost. However, empirical evidence suggests that the inventory cost is small (Hasbrouck, 1988; Stoll, 1989; Madhavan and Smidt, 1991). Therefore, we do not distinguish between the order processing and inventory costs.

cost, which includes the market maker's opportunity cost, administration cost, and inventory-related cost.[10] The order processing cost seems to vary little over a period of a few months. With more trades during the time period, the order processing cost allocated to each trade diminishes. On the other hand, the larger the daily average number of trades, the smaller the asymmetric information component of the spread. This is because trading frequency is positively related to the informativeness of stock prices. Combining these two factors, the bid–ask spread should be inversely related to the number of trades and frequently traded stocks should be bound by the $\$\frac{1}{8}$ minimum price variation more than less frequently traded stocks.

The evidence that the AMEX tick-size change affects the quoted spread minimally for inactive stocks suggests that specialists do not use a $\$\frac{1}{16}$ spread as frequently as predicted. Table IV not only confirms this conjecture but also reveals a rich pattern of clustering. Harris (1994) predicts a monotonic decline in frequencies: $\$\frac{1}{16}$ (44.6%) will be the most popular followed by $\$\frac{1}{8}$ (44.2%), $\$\frac{3}{16}$ (9.7%), and $\$\frac{1}{4}$ (1.3%). By contrast, the observed pattern is not monotonically decreasing but bimodal. For the group of inactive stocks, the most frequently used spread is still $\$\frac{1}{4}$ (50.6%) followed by $\$\frac{1}{8}$ (42.1%). The use of $\$\frac{1}{16}$ (1.7%) and $\$\frac{3}{16}$ (3.2%) is negligible. For actively traded stocks, $\$\frac{1}{8}$ (50.6%) is the most popular spread followed by $\$\frac{1}{16}$ (27.6%), $\$\frac{1}{4}$ (16.9%), and $\$\frac{3}{16}$ (4.6%). This indicates that specialists do not use $\$\frac{3}{16}$ as often as $\$\frac{1}{8}$ or $\$\frac{1}{4}$. We conjecture that the unpopularity of $\$\frac{3}{16}$ may be related to the negotiation cost as suggested by Harris (1991).

B. *The Effective Spread*

We now turn to the analysis of the effective spread, which is a more accurate measure of the transaction costs paid by investors. Blume and Goldstein (1992), Lee and Ready (1991), and McInish and Wood (1995) document that a substantial portion of actual transactions are executed at prices better than the posted quotes. Thus, the effective spread is smaller than the quoted spread. We define the effective spread of a given trade as $2|p_t - q_t|$, where p_t is the transaction price at time t, and q_t is the midpoint of bid and ask quotes at t. This definition recognizes the possibility of trades being executed between the bid and ask quotes. Such trades may arise from the existence of limit orders that are better than the standing quotes but are not posted (McInish and Wood, 1995) or from competition from floor brokers. Lee and Ready (1991) report that trades are often reported with a lag and suggest comparing trades to the quote reported at least 5

[10] Glosten and Harris (1988) report that only 20% of the spread is attributable to information asymmetry. George *et al.* (1991) also report that the asymmetric information component is relatively small.

TABLE IV
THE FREQUENCY OF THE QUOTED SPREAD FOR THE AMEX STOCKS SORTED BY TRADING FREQUENCY ($1–$5 PRICE GROUP)

	No. of trades ≤ 1.65 (N = 53)			1.65 < No. of trades ≤ 4.90 (N = 53)			4.90 < No. of trades (N = 53)		
	Before	After	Difference	Before	After	Difference	Before	After	Difference
$\$\frac{1}{16}$	0.00	1.70	1.70**	0.00	5.90	5.90**	0.00	27.64	27.64**
	(0.00)	(0.51)	(0.51)	(0.00)	(1.00)	(1.00)	(0.00)	(3.39)	(3.39)
$\$\frac{1}{8}$	39.00	42.08	3.08	53.21	50.23	−2.98	71.51	50.56	−20.95**
	(2.93)	(2.49)	(2.40)	(1.55)	(1.50)	(1.47)	(1.90)	(1.93)	(3.02)
$\$\frac{3}{16}$	0.00	3.24	3.24**	0.00	5.32	5.32**	0.00	4.61	4.61**
	(0.00)	(0.60)	(0.60)	(0.00)	(0.87)	(0.87)	(0.00)	(0.50)	(0.50)
$\$\frac{1}{4}$	57.22	50.61	−6.61*	46.09	38.04	−8.05**	27.57	16.87	−10.70**
	(2.67)	(2.55)	(2.85)	(1.49)	(1.89)	(1.76)	(1.63)	(1.98)	(1.29)
$\$\frac{5}{16}$	0.00	0.24	0.24	0.00	0.11	0.11	0.00	0.05	0.05**
	(0.00)	(0.11)	(0.11)	(0.00)	(0.04)	(0.04)	(0.00)	(0.02)	(0.02)
$\$\frac{3}{8}$	3.63	2.13	−1.50	0.67	0.41	−0.26	0.83	0.26	−0.57
	(1.32)	(0.69)	(0.95)	(0.18)	(0.10)	(0.19)	(0.50)	(0.13)	(0.38)
$\$\frac{7}{16}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\$\frac{1}{2}$ and above	0.15	0.00	−0.15	0.02	0.00	−0.02	0.09	0.00	−0.09
	(0.15)	(0.00)	(0.15)	(0.02)	(0.00)	(0.02)	(0.09)	(0.00)	(0.09)

Note. The percentage frequencies of the quoted spread at $\$\frac{1}{16}$, $\$\frac{1}{8}$, $\$\frac{3}{16}$, $\$\frac{1}{4}$, $\$\frac{5}{16}$, $\$\frac{3}{8}$, $\$\frac{7}{16}$, and $\$\frac{1}{2}$ and above are measured for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. All stocks in the sample are partitioned into three groups based on average daily number of trades in the pre-event period. The quoted spread is calculated as the difference between the ask and bid quotes. The cross-sectional means and standard errors (in parentheses) are reported.

*,** Significant at the 0.05 and 0.01 levels (two-tailed), respectively, using the Wilcoxon test. The null hypothesis of the test is that there is no difference in frequency changes between the AMEX $1–$5 trade-size group and the AMEX $5–$10 group. For each stock in the AMEX $5–$10 group, we adjust the frequency changes by the factor

$$\left[\frac{\text{cross-sectional mean change for NYSE \$1–\$5 group}}{\text{cross-sectional mean change for NYSE \$5–\$10 group}}\right].$$

sec ahead of the trade. Following their suggestion, we define the prevailing quote as the latest posted at least 5 sec prior to the reported transaction time.

Table V gives summary statistics for the effective spread per share in both the pre- and post-event periods for stocks traded on the AMEX and the NYSE. As expected, effective spreads are smaller than quoted spreads. The average effective spread is 14.2 cents (Panel A, Table V), compared to 18.4 cents of the quoted spread for the AMEX stocks ($1–$5) during the pre-event period (Panel A, Table II). For the AMEX stocks priced $1–$5, the change in tick size leads to a reduction in the effective spread by about 1 cent (from 14.2 to 12.9 cents), a 7.5% reduction. This decline in the effective spread is statistically significant. The results for the two control samples indicate that there is no significant change in the effective

TABLE V
THE EFFECTIVE SPREAD (IN CENTS) FOR THE AMEX AND NYSE STOCKS

	A. AMEX stocks					
	$1–$5 (N = 159)			$5–$10 (N = 145)		
	Before	After	Change (%)	Before	After	Change (%)
Mean	14.18	12.85	−7.51	16.44	16.18	−0.05
(S.E.)	(0.28)	(0.28)	(1.91)	(0.35)	(0.34)	(1.40)
Median	13.45	12.50	−7.80	15.08	15.57	−1.08
	B. NYSE stocks					
	$1–$5 (N = 125)			$5–$10 (N = 252)		
	Before	After	Change (%)	Before	After	Change (%)
Mean	12.62	12.60	1.30	13.66	13.76	0.76
(S.E.)	(0.20)	(0.17)	(1.42)	(0.17)	(0.21)	(0.88)
Median	12.13	12.17	−0.88	12.89	13.02	0.10

C. Tests of the null hypothesis that there is no difference in percentage changes between the AMEX $1–$5 group and each of the three benchmark groups; p values are reported

Benchmark group	F-test	Wilcoxon test
AMEX $5–$10 stocks	0.002	0.000
AMEX $5–$10 stocks (adjusted)[a]	0.015	0.002
NSYE $1–$5 stocks	0.000	0.000

Note. The effective spread and percentage change in the effective spread are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t.

[a] For each stock, the adjustment factor is

$$\left[\frac{\text{cross-sectional mean \% change for NYSE \$1–\$5 group}}{\text{cross-sectional mean \% change for NYSE \$5–\$10 group}}\right].$$

spread for the AMEX $5–$10 stocks and for the NYSE $1–$5 stocks. All test statistics reported in Panel C are significant at the 5% level. Thus, the reduction in the effective spread for low-price AMEX stocks seems to be attributable to the change in tick size.

The impact of the tick-size change on the AMEX stocks priced $1–$5 with different trading frequencies is reported in Table VI. For inactively

TABLE VI
THE EFFECTIVE SPREAD (IN CENTS) FOR THE AMEX STOCKS SORTED BY TRADING FREQUENCY ($1–$5 PRICE GROUP)

A. Summary statistics

	No. of trades ≤ 1.65 (N = 53)			1.65 < No. of trades ≤ 4.90 (N = 53)			4.90 < No. of trades (N = 53)		
	Before	After	Change (%)	Before	After	Change (%)	Before	After	Change (%)
Mean	15.63	15.07	2.18	13.88	13.00	−4.86	13.10	10.64	−18.89
(S.E.)	(0.71)	(0.55)	(4.46)	(0.33)	(0.30)	(2.20)	(0.29)	(0.37)	(2.34)
Median	15.31	14.87	2.39	13.85	13.21	−5.62	12.63	10.46	−21.87

B. Tests of the null hypothesis that there is no difference in percentage changes between the AMEX $1–$5 group and each of the three benchmark groups; p values are reported

	No. of trades ≤ 1.65		1.65 < No. of trades ≤ 4.90		4.90 < No. of trades	
Benchmark Group	F-test	Wilcoxon test	F-test	Wilcoxon test	F-test	Wilcoxon test
AMEX $5–$10 stocks	0.527	0.639	0.075	0.057	0.000	0.000
AMEX $5–$10 stocks (adjusted)[a]	0.643	0.817	0.259	0.183	0.000	0.000
NYSE $1–$5 stocks	0.805	0.806	0.020	0.036	0.000	0.000

Note. The effective spread and the percentage change in the effective spread are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. All stocks in the sample are partitioned into three groups based on average daily number of trades in the pre-event period. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t.

[a] For each stock, the adjustment factor is

$$\left[\frac{\text{cross-sectional mean \% change for NYSE \$1–\$5 group}}{\text{cross-sectional mean \% change for NYSE \$5–\$10 group}}\right].$$

traded stocks, the effective spread does not materially change (from 15.6 to 15.1 cents). In contrast, the effective spread drops by 2.5 cents (from 13.1 to 10.6 cents) for the most actively traded stocks, a 19% reduction. The test statistics in Panel B show that the change in the effective spread is significant at the 1% level for the frequently traded group.

C. *Trading Volume and Market Depth*

The previous section documents that the AMEX tick-size change affects both the quoted and effective spreads. However, a careful analysis of welfare effects should precede any change in trading practices. For example, one argument against the decimal pricing system is that market makers

may reduce quotes and their support of infrequently traded stocks. The liquidity of the market may suffer as a consequence. On the other hand, proponents of the decimal convention usually argue that market liquidity will be improved because it is cheaper to trade. In addition, the market maker's loss due to narrower spreads will be compensated for by an increase in trading volume. The latter argument is conceptually appealing because trading volume is negatively related to transaction costs and thus to the bid–ask spread. If the profit generated from additional trading volume can offset the loss due to the decrease in the bid–ask spread, market makers will be no worse off than before the change. Thus, reducing the tick size would be a Pareto improvement. We now examine changes in trading volume and market depth following the AMEX tick-size rule change.

In Table VII, we report summary statistics of three different measures of trading volume in the pre- and post-event periods: trading frequency, share volume, and dollar volume. Since the distribution of any one of these variables is skewed (see Table I), we use the ratio of post-event volume to pre-event volume and take the natural log of the ratio to obtain our test statistics. For the AMEX stocks affected by the new tick-size rule, Table VII suggests that all three measures of volume increase after September 3, 1992. For example, the average daily share volume is 9,405 shares in the pre-event period and 14,828 shares in the post-event period for the AMEX stocks priced between \$1 and \$5. However, stocks that are not affected by the tick-size change also experience an increase in volume during the post-event period. For example, for the AMEX \$1–\$5 stocks, the change in daily share volume is about 22%. For the AMEX stocks in the \$5–\$10 price range, the increase is about 10%. For the NYSE stocks priced between \$1 and \$5, the increase is about 18%. Indeed, test statistics in Panel C suggest that the changes in the volume variables for the AMEX \$1–\$5 group are not statistically different from those of the other control groups.[11] Thus, the increase in volume is likely to be related to a common factor such as a time trend, rather than being caused by the tick-rule change.

Table VII reveals that the ask and bid quantities per quote do not change significantly in the post-event period. For low-price AMEX stocks (\$1–\$5), the average ask is 3,460 shares in the pre-event period and 3,129 shares in the post-event period. For the bid, the averages are 3,960 and 3,309, respectively. Again, the change is not statistically different from that of any of the other control groups, suggesting that the reduction in the minimum price variation does not affect market depth in general.

Examining three subsamples partitioned by the average number of transactions does not alter the conclusion (Table VIII). While inactive stocks

[11] We report the test for only one hypothesis; however, the results for the other two null hypotheses are similar.

TABLE VII
THE IMPACT OF THE AMEX TICK RULE CHANGE ON THE TRADING VOLUME AND MARKET DEPTH

	A. AMEX stocks					
	\$1–\$5 (N = 159)			\$5–\$10 (N = 145)		
	Before	After	Logarithmic difference (%)	Before	After	Logarithmic difference (%)
No. of trades	5.82	7.18	16.33	9.59	10.72	8.06
	(0.70)	(0.95)	(3.97)	(1.55)	(1.75)	(4.08)
Share volume in 100's	94.05	148.28	22.22	146.72	168.20	10.26
	(15.96)	(34.71)	(5.86)	(34.45)	(36.84)	(5.99)
Dollar volume in \$100's	328.25	479.08	14.36	1088.39	1209.42	9.14
	(55.35)	(105.99)	(6.39)	(243.15)	(241.73)	(6.25)
Ask size per quote in 100's	34.60	31.29	1.47	31.07	24.16	1.22
	(5.35)	(3.88)	(4.09)	(4.78)	(2.47)	(4.20)
Bid size per quote in 100's	39.60	33.09	−5.27	29.49	22.81	−0.02
	(5.01)	(3.39)	(4.17)	(4.30)	(2.00)	(4.13)
	B. NYSE stocks					
	\$1–\$5 (N = 125)			\$5–\$10 (N = 252)		
	Before	After	Logarithmic difference (%)	Before	After	Logarithmic difference (%)
No. of trades	12.07	13.20	15.29	23.96	25.81	7.42
	(1.12)	(1.08)	(3.71)	(1.47)	(1.65)	(2.55)
Share volume in 100's	281.43	308.12	17.84	475.27	507.72	6.13
	(51.87)	(51.75)	(5.28)	(45.85)	(45.62)	(3.21)
Dollar volume in \$100's	928.70	961.16	13.89	3891.74	4075.15	3.70
	(135.73)	(135.88)	(6.43)	(351.83)	(362.22)	(3.34)
Ask size per quote in 100's	106.18	110.41	12.23	162.59	142.48	−6.43
	(13.10)	(12.67)	(4.13)	(13.74)	(12.17)	(2.46)
Bid size per quote in 100's	116.26	113.49	2.02	152.79	137.22	−5.10
	(12.81)	(11.63)	(4.45)	(12.81)	(13.48)	(2.53)

exhibit an increase in trading volume, the increase seems economically trivial. For the most actively traded stocks, there is neither a significant increase in trading volume nor a significant decrease in market depth.

Collectively, the evidence from the post-event period suggests that the reduction in tick size from $\$\frac{1}{8}$ to $\$\frac{1}{16}$ does not generate additional volume, nor does it affect market depth. Investors benefit from the lower transaction costs, but market makers suffer because the effective spread is narrower without a significant increase in trading volume.

TABLE VII—*Continued*

	C. Tests of the null hypothesis for equality of logarithmic differences between the AMEX \$1–\$5 group and the AMEX \$5–\$10 group (adjusted)[a]; *p* values are reported	
	F-test	Wilcoxon test
No. of trades	0.975	0.503
Share volume in 100's	0.667	0.775
Dollar volume in \$100's	0.394	0.692
Ask size per quote in 100's	0.664	0.655
Bid size per quote in 100's	0.259	0.158

Note. The average daily number of trades, daily share volume, daily dollar volume, ask size, and bid size per quote are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. The cross-sectional means and standard errors (in parentheses) are reported in panels A and B.

[a] For each stock, the adjustment factor is

$$\left[\frac{\text{cross-sectional mean logarithmic difference for NYSE \$1–\$5 group}}{\text{cross-sectional mean logarithmic difference for NYSE \$5–\$10 group}}\right].$$

D. *Cross-Sectional Regression Results*

In this section, we examine the determinants of the change in the posted and effective spreads and the usage frequency of $\$\frac{1}{16}$ and $\$\frac{1}{8}$ by performing cross-sectional regression analysis for the AMEX \$1–\$5 stock sample. The regression model is given by

$$Y_i = \alpha + \beta_1 \log(\text{NTrade})_i + \beta_2 \text{AvePrice}_i + \beta_3 \log(\text{Primary})_i + \varepsilon_i, \quad (1)$$

where i denotes a stock and

Y = the difference (or the percentage change) in the posted spread, the effective spread, or the $\$\frac{1}{16}$ or $\$\frac{1}{8}$ usage frequency between the pre- and post-event periods

log(NTrade) = the log of the average daily number of trades

AvePrice = the average daily closing price

log(Primary) = the log of the fraction of average daily primary market share volume to the average daily total volume.

We use three explanatory variables, the average daily number of trades, the average daily closing price, and the fraction of the average daily primary

TABLE VIII

THE IMPACT OF THE AMEX TICK RULE CHANGE ON THE TRADING VOLUME AND MARKET DEPTH FOR THE AMEX STOCKS SORTED BY TRADING FREQUENCY ($1–$5 PRICE GROUP)

	No. of trades ≤ 1.65 (N = 53)			1.65 < No. of trades ≤ 4.90 (N = 53)			4.90 < No. of trades (N = 53)		
	Before	After	Logarithmic difference (%)	Before	After	Logarithmic difference (%)	Before	After	Logarithmic difference (%)
No. of trades	0.85	1.28	32.22	3.00	3.60	10.62	13.62	16.65	6.71
	(0.05)	(0.13)	(6.29)	(0.12)	(0.26)	(5.76)	(1.63)	(2.33)	(7.98)
Share volume in 100's	8.65	15.89	37.28	32.80	43.61	19.17	240.69	385.36	10.20
	(0.89)	(2.73)	(10.51)	(2.76)	(4.02)	(8.49)	(41.08)	(96.58)	(11.10)
Dollar volume in $100's	24.43	42.83	34.67	115.91	133.92	4.40	844.40	1260.49	3.99
	(2.40)	(6.84)	(10.77)	(11.33)	(15.16)	(9.24)	(141.50)	(290.56)	(12.62)
Ask size per quote in 100's	12.57	14.77	13.53	19.74	18.90	0.61	71.47	60.20	−9.74
	(1.63)	(1.69)	(8.18)	(1.70)	(1.30)	(6.00)	(14.70)	(10.40)	(6.67)
Bid size per quote in 100's	24.71	19.01	2.60	24.62	22.65	−5.89	69.46	57.62	−12.53
	(6.59)	(3.06)	(8.72)	(2.18)	(1.65)	(6.10)	(12.44)	(8.66)	(6.58)

Note. The average daily number of trades, daily share volume, daily dollar volume, ask size, and bid size per quote are calculated for the three-month periods before and after September 3, 1992, the day on which the new tick size rule became effective. All stocks in the sample are partitioned into three groups based on average daily number of trades in the pre-event period. The cross-sectional means and standard errors (in parentheses) are reported.

market share volume relative to the daily average total volume. To address a potential endogeneity problem, all explantory variables are limited to pre-event period data. The endogeneity problem may arise because the reduction in tick size may affect the explanatory variables as well. Since the distribution of the number of trades and the fraction of primary market volume are skewed, these variables are log-transformed.

The selection of explanatory variables is motivated by Harris (1994).[12] As shown earlier, the $\$\frac{1}{8}$ minimum price variation is more likely to bind actively traded stocks than infrequently traded ones. Similarly, it is more likely to bind low-priced stocks than high-priced stocks because a lower priced stock has a larger ''effective'' tick size. The fraction of primary market volume measures the degree of competition between the primary exchange (i.e., AMEX) and regional exchanges. We expect that the minimum price variation would be a more binding constraint for stocks traded in a more competitive environment. In brief, we predict that stocks with greater trading activity, lower prices, and greater competition from the regional exchanges are likely to experience greater spread reductions, a greater increase in the $\$\frac{1}{16}$ usage and a greater decrease in the $\$\frac{1}{8}$ usage.

Table IX displays results that are consistent with the above predictions. In the first regression, the dependent variable is the difference in the spread (in cents) between the pre- and post-event periods. The estimated coefficients (*t*-stat.) of the three explanatory variables, log(NTrade), AvePrice, and log(Primary), are −0.78 (−4.4), 0.49 (3.2), and 3.04 (2.0), respectively. All three coefficients are significant at the 5% level and their signs are consistent with the predictions. The adjusted R^2 is 0.27. The results are similar when we use the percentage change in the spread, the difference in the effective spread, and the percentage change in the effective spread. When we use the difference in the $\$\frac{1}{8}$ (or $\$\frac{1}{16}$) usage frequency as the dependent variable, the regression results show that both the number of trades and the average price are significant at the 5% level and their signs are as expected. The sign of the fraction of primary market volume is as expected, although the coefficient estimate is not statistically significant. Specifically, for the $\$\frac{1}{16}$ usage frequency, the estimated coefficients (*t*-stat.) for the three explanatory variables are 11.86 (9.7), −4.05 (−3.8), and −10.70 (−1.0), respectively. The adjusted R^2 is 0.54.[13]

[12] We also experimented with several other independent variables including the weekly return standard deviation, average daily market value of the outstanding shares, and average daily primary market volume. These variables are either insignificant or highly correlated with one of the three variables used.

[13] We also considered differences in the trading volume, the bid and ask quantities as dependent variables. In general, the estimated coefficients were insignificant and the adjusted R^2's were low. This evidence is consistent with our previous result that changes in trading volume and market depth are insignificantly affected by the tick-size change. To conserve space, these results are not reported in Table IX.

TABLE IX
Cross-sectional Regressions of the Changes in the Spread, Effective Spread, and Spread Frequencies on Variables Representing Stock Characteristics

Dependent Variable (Y)	α	β_1	β_2	β_3	Adj. R^2
(1) QSprDiff	−1.94	−0.78	0.49	3.04	
	(−3.60)	(−4.36)	(3.15)	(2.00)	.27
(2) QSprRatio	−9.44	−6.15	2.96	14.31	
	(−3.12)	(−6.16)	(3.39)	(1.68)	.37
(3) ESprDiff	−0.20	−0.61	0.30	7.84	
	(−0.21)	(−1.96)	(1.08)	(2.92)	.16
(4) ESprRatio	−0.30	−8.52	3.76	40.08	
	(−0.04)	(−3.62)	(1.82)	(1.99)	.21
(5) $\$\frac{1}{16}$FreqDiff	6.74	11.86	−4.05	−10.70	
	(1.81)	(9.68)	(−3.77)	(−1.02)	.54
(6) $\$\frac{1}{8}$FreqDiff	1.01	−10.97	2.69	1.04	
	(0.23)	(−7.67)	(2.15)	(0.09)	.40

Note. Six dependent variables are used separately in the regressions: (1) QSprDiff, the difference in the quoted spread; (2) QSprRatio, the percentage change in the quoted spread; (3) ESprDiff, the difference in the effective spread; (4) ESprRatio, the percentage change in the effective spread; (5) $\$\frac{1}{16}$FreqDiff, the difference in the frequency of $\$\frac{1}{16}$ spread; and (6) $\$\frac{1}{8}$FreqDiff, the difference in the frequency of $\$\frac{1}{8}$ spread. The dependent variables are changes between the three-month period before September 3, 1992 and the three-month period after the date on which the new tick size rule became effective. Three independent variables are used in each regression: (1) log(NTrade), the log of the average daily number of trades; (2) AvePrice, the average stock price; and (3) log(Primary), the log of the fraction of average daily primary market share volume to the average daily consolidated share volume. All independent variables are calculated from the three-month period prior to September 3, 1992. The regression coefficients and their t-statistics (in parentheses) are reported.

E. *Discussion*

For actively traded stocks, the impact of the exchange rule change on the spread and usage frequencies of $\$\frac{1}{16}$ and $\$\frac{1}{8}$ are generally consistent with Harris' (1994) prediction. The magnitudes of the changes in these variables, however, are smaller than Harris predicted. Furthermore, the absence of significant increase in trading volume and significant decrease in market depth is at variance with Harris' prediction. There is a possible explanation for this discrepancy. Harris' work is based on a cross-sectional interpolation technique which predicts the unobserved $\$\frac{1}{16}$ spread frequency from the other observed spread (i.e., multiples of $\$\frac{1}{8}$) frequencies. Although this is a reasonable technique given that minimum price variation does not change in his sample, there is no guarantee that the cross-sectional interpolation is flawless. As Harris points out, his predictions are based on two important assumptions: (1) price level is the only factor that causes the "relative"

tick size to change and (2) price level determines market quality exclusively through its impact on the minimum price variation. As Harris cautions (p. 176), ''If price level affects market quality through other mechanisms, the interpretations in this study would be suspect. The interpretations also would be suspect if price level is correlated with omitted variables that affect market quality.''

F. *Welfare Implications*

Based on the estimates of the effective spread per share, we calculate the estimated transaction costs paid by investors. Since trading volume is dominated by the stocks in the most actively traded group, we focus on these. From Table VI, the effective spread is 10.64 cents for stocks in the most active group during the three-month post-event period. The average daily share volume is 38,536 shares (Table VIII). Thus, the total transaction costs paid by investors are about \$13.7 million (\$0.1064 spread $\times$ 38,536 shares $\times$ 63 trading days $\times$ 53 stocks).[14]

The reduction in the effective spread from the pre-event to the post-event period is 2.46 cents per share (from 13.10 to 10.64 cents) for the most actively traded stocks (Table VI). Assuming that the same number of shares would have been traded during the post-event three-month period without a reduction in tick size, the savings in transaction costs is about \$3.2 million (\$0.0246 spread change $\times$ 38,536 shares $\times$ 63 trading days $\times$ 53 stocks). The annualized savings for these 53 actively traded stocks would be about \$12.8 million, or 20 percent of the total transaction costs. Because there is no significant increase in trading volume generated by the smaller tick, the reduction in the effective spread following the new tick-size rule implies that there is a wealth transfer from market makers to investors.[15] Since our calculation is for low-price AMEX stocks only, savings in transaction costs would be much larger if we included the NYSE and AMEX stocks with prices of \$5 or more, provided that a similar reduction in the effective spread of these stocks would ensue.

5. CONCLUSION

This paper examines the impact of the change in the minimum price variation on transaction costs, trading volume and market depth. We focus on AMEX stocks traded at prices between \$1 and \$5 affected by the new

[14] There are 63 valid trading days in the three-month period.

[15] We also examined whether the fraction of share volume generated from the primary market to total share volume changed in response to the tick-size change. We failed to find a significant change.

tick-size rule, effective September 3, 1992. There are many arguments for and against the change in the tick-size as well as the decimal pricing system, but most of them are heuristic and judgmental. This paper is the first that presents direct evidence on the impact of reducing minimum price variation on transaction costs and trading activity. We find a substantial reduction in both quoted and effective spreads following the AMEX's reduction in tick-size from $\$\frac{1}{8}$ to $\$\frac{1}{16}$. However, the rule change affected neither trading volume nor market depth. Investors' savings in transaction costs came at the expense of market makers.

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