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Spreads, Depths, and Quote Clustering on the NYSE and Nasdaq: Evidence after the 1997 Securities and Exchange Commission Rule Changes

Kee H. Chung*

State University of New York at Buffalo

Bonnie F. Van Ness

University of Mississippi

Robert A. Van Ness

University of Mississippi

Abstract

This paper examines liquidity and quote clustering on the NYSE and Nasdaq using data after the two market reforms—the 1997 order-handling rule and minimum tick size changes. We find that Nasdaq-listed stocks exhibit wider spreads and smaller depths than NYSE-listed stocks and stocks with higher proportions of even-eighth and even-sixteenth quotes have wider quoted, effective, and realized spreads on both the NYSE and Nasdaq. This result differs from the findings by Bessembinder (1999, p. 404) that "trade execution costs on Nasdaq in late 1997 are no longer significantly explained by a tendency for liquidity providers to avoid

**Corresponding author*: Department of Finance and Managerial Economics, School of Management, State University of New York at Buffalo, Buffalo, NY 14260; Phone: (716) 645-3262; E-mail: keechung@acsu.buffalo.edu

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odd-eighth quotations," and "odd-sixteenth avoidance has little relevance for explaining post-reform Nasdaq trading costs."

Keywords: liquidity, spreads, depths, quote clustering, collusion

JEL Classifications: G14/G18

1. Introduction

Numerous studies show that trading costs on Nasdaq are significantly greater than those on the NYSE. For example, Goldstein (1993), Christie and Schultz (1994), Huang and Stoll (1996), and Bessembinder and Kaufman (1997, 1998) find that both the quoted and the effective spreads of stocks traded on Nasdaq are wider than those of comparable stocks traded on the NYSE. In addition, Christie and Huang (1994) and Barclay (1997) find that spreads become narrower when stocks move from Nasdaq to the NYSE. Christie and Schultz (1994) maintain that Nasdaq dealers implicitly collude to set wider spreads than their NYSE counterparts, based on their finding that stocks listed on Nasdaq exhibit fewer odd-eighth quotes than comparable stocks on the NYSE.

The public disclosure of Christie and Schultz's (1994) findings rekindled debates on the efficacy of the Nasdaq system. During the summer of 1994, numerous class-action lawsuits were filed in California, Illinois, and New York against Nasdaq market makers.[1] Prompted by renewed debates and also by legal action taken against Nasdaq market makers, both the Department of Justice and the Securities and Exchange Commission (SEC) undertook regulatory investigations into the issue. These investigations led to a series of reforms on Nasdaq. First, the Department of Justice investigation prompted market makers to curb the practice of avoiding odd-eighth quotes. Second, NASD Regulation Inc. was created to take over the regulatory responsibilities of the National Association of Securities Dealers. Third, the SEC enacted sweeping changes in the order-handling rules on Nasdaq.

On January 20, 1997, the phase-in of the new SEC order-handling rules began.[2] The first rule, known as the "Limit Order Display Rule," requires that limit orders be displayed in the Nasdaq best bid and offer (BBO) when they are better than quotes posted by market makers. This new rule allows the general public to compete directly with Nasdaq market makers in the quote-setting process. The second SEC rule, known as the "Quote Rule," requires market makers to publicly display their most competitive quotes. This rule allows the public access to superior quotes posted by market makers in Electronic Communication Networks (ECNs).[3] Under the new

[1] These lawsuits were later consolidated into a single class-action suit in the Southern District of New York.

[2] These new rules were phased in for all Nasdaq National Market System issues by October 13, 1997.

[3] ECNs are proprietary trading systems such as Instinet that are used exclusively by market makers and large institutions.

rule, if a dealer places a limit order into Instinet or another ECN, the price and quantity are incorporated in the ECN quote displayed on Nasdaq.

Barclay, Christie, Harris, Kandel, and Schultz (1999) examine the effect of these changes on Nasdaq trading costs for the first 100 stocks phased in under the new rules. They find that quoted and effective spreads decline by about 30%, with the largest decline observed for the group of stocks with relatively wide spreads prior to the rule changes. They also find that approximately 60% of the total decline in trading costs for Nasdaq stocks between January 1994 and February 1997 arose prior to the introduction of the new SEC rules. They attribute this pre-reform decline in spreads to various government investigations and negative publicity directed at Nasdaq dealers ignited by the results in Christie and Schultz (1994).

On June 2, 1997, the minimum tick size on Nasdaq changed from \$1/8 to \$1/16 for stocks with a price greater than \$10. A similar change occurred for NYSE stocks on June 24, 1997. Simaan, Weaver, and Whitcomb (1998) investigate the quotation behavior of Nasdaq market makers following the tick size change. They find that Nasdaq market makers continue to avoid odd ticks, but traders entering orders on ECNs do not exhibit the same behavior. Their findings show that ECNs frequently establish the inside market quote and reduce trading costs for the public about 19% of the time.

Overall, both academic research and anecdotal evidence suggest that trading costs for Nasdaq issues have declined significantly since the public dissemination of the Christie and Schultz findings, and particularly since the implementation of the new SEC rules. Given the results of pre-reform studies (see, e.g., Christie and Schultz, 1994; Huang and Stoll, 1996; Bessembinder and Kaufman, 1997) that trading costs on Nasdaq are significantly greater than those on the NYSE, it would be of great interest to both regulatory authorities and the general public to know whether investors incur larger trading costs on Nasdaq than on the NYSE after the implementation of the new SEC rules and the new tick size.[4]

We compare trading costs and depths between Nasdaq-listed and NYSE-listed stocks using data on 460 matching pairs of Nasdaq and NYSE stocks during a three-month period from February 1, 1998, to April 30, 1998.[5] Bessembinder (1999) also performs a post-reform comparison of execution costs between Nasdaq and NYSE stocks. Our study differs from his study in two important ways. First, whereas

[4] Jones and Lipson (1999) compare execution costs across the major U.S. exchanges using a sample of institutional equity orders in firms that switch exchanges and find that execution costs including commissions are not different across these exchanges.

[5] Demsetz (1997) suggests that the excess of Nasdaq spreads over NYSE spreads reported in Christie and Schultz (1994) may not necessarily be an indication of collusion among Nasdaq dealers. Demsetz suggests that Nasdaq spreads are likely to be larger than NYSE spreads even in the absence of the alleged collusion because spreads on the Nasdaq were set exclusively by dealers, whereas NYSE spreads were set by both specialists and limit order traders. Because Nasdaq spreads reflect the interest of both market makers and limit order traders in our post-reform data, our study is not subject to the same criticism.

Bessembinder focuses on the difference in spreads between Nasdaq and NYSE stocks, we examine differences in depths as well. We consider this important because the spread captures only one dimension of liquidity. As shown in Lee, Mucklow, and Ready (1993), Harris (1994), Kavajecz (1999), Goldstein and Kavajecz (2000), and Jones and Lipson (2001), it is necessary that we consider both the price and quantity dimensions of dealer quotes to accurately measure liquidity. Second, we employ a different approach for the analysis of the effect of quote clustering on spreads. Specifically, we calculate the "residual spread" that is orthogonal to stock attributes and test whether quote clustering has any impact on the spread. This enables us to accurately measure the net effect of quote clustering on spreads after controlling for other determinants of spreads.

Our empirical results show that Nasdaq market makers post wider spreads than NYSE specialists, despite the fact that Nasdaq spreads have declined significantly during the last several years. We also find that Nasdaq market makers post significantly smaller depths than NYSE specialists. The results show that the proportion of even-sixteenth quotes is higher than the proportion of odd-sixteenths on both the NYSE and Nasdaq and stocks with higher proportions of even-sixteenth quotes have wider spreads.

The paper is organized as follows. Section 2 describes our data and stock matching procedure. Section 3 explains our measures of trading costs. Section 4 presents a detailed analysis of the differential trading costs and depths between Nasdaq and NYSE stocks. Section 5 examines the effect of quote clustering on trading costs. Section 6 presents the results of sensitivity analyses with respect to different matching methods. Section 7 concludes.

2. Data source and sample selection

We obtain data for this study from the NYSE's Trade and Quote (TAQ) database. Additionally, we obtain dealer quote data from Nasdaq for depth computation. We begin our sample selection by identifying Nasdaq stocks for which the new SEC rules were in effect as of June 30, 1997. This initial sample comprises 650 stocks that are included in the first 13 batches of Nasdaq stocks phased in under the new SEC rules.[6] Of these 650 stocks, we find only 624 stocks on the list of stocks under the new rules posted on the National Association of Securities Dealers Web site.[7] Of these 624 stocks on the list, we are able to obtain data on 551 stocks from the TAQ database for our study period from February 1, 1998, to April 30, 1998. Of the remaining 551 stocks, we obtain depth data from Nasdaq for only 508 stocks. Because our study

[6] The dates on which the new SEC rules became effective for 13 batches of 50 stocks are: January 20, February 10, February 24, April 21, April 28, May 5, May 12, May 19, May 27, June 2, June 9, June 23, and June 30.

[7] The discrepancy (26 stocks) may be due to some Nasdaq stocks moving to other exchanges or going bankrupt after being subject to the new SEC rules.

period starts at February 1, 1998, our choice of June 30 as the cut-off point ensures at least a seven-month assimilation period for the new rules.

Before we match our Nasdaq stocks with their counterparts on the NYSE, we precondition our data to minimize errors. We omit trades and quotes if the TAQ database indicates that they are out of time sequence, involve an error, or involve a correction. We omit quotes if either the ask or the bid price is equal to or less than zero. Similarly, we omit quotes if either the bid or ask depth is equal to or less than zero. We omit trades if the price or volume is equal to or less than zero. As in Huang and Stoll (1996), we omit the following to further minimize data errors: quotes when the spread is greater than \$4 or less than zero; before-the-open and after-the-close trades and quotes; trade price, p_t, when $|(p_t - p_{t-1})/p_{t-1}| > 0.10$; ask quote, a_t, when $|(a_t - a_{t-1})/a_{t-1}| > 0.10$; and bid quote, b_t, when $|(b_t - b_{t-1})/b_{t-1}| > 0.10$.

We measure share price by the mean value of the midpoints of quoted bid and ask prices and return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices.[8] We recognize that the reported number of trades on Nasdaq is not directly comparable to that on the NYSE because there are many inter-dealer trades on Nasdaq.[9] Because inter-dealer trades exaggerate the reported volume, Nasdaq volume tends to be larger than the NYSE volume. We measure the number of trades for NYSE-listed stocks using transactions on both the NYSE and other markets (i.e., regional and over-the-counter markets) to counterbalance the effect of inter-dealer trades on the reported volume of Nasdaq-listed stocks.[10] We measure trade size by the average dollar transaction during the study period.

Following Bessembinder (1999), we match each stock in the Nasdaq sample with its NYSE counterpart based on the market value of equity (MVE). We first calculate the following match score (MS) for each Nasdaq stock in our sample against each of the 2,912 NYSE stocks in the TAQ database:[11]

$$\text{MS} = [(\text{MVE}^{\text{N}} - \text{MVE}^{\text{Y}})/(\text{MVE}^{\text{N}} + \text{MVE}^{\text{Y}})/2]^2 \qquad (1)$$

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[8] We drop a stock from the study sample if its mean share price during the study period is less than \$1.

[9] Nasdaq uses the same volume counting rules as the NYSE. Every time a trade occurs, either between two market makers, a market maker and a customer, or two customers, it is counted as one trade. The factor that makes it difficult to compare volumes of the two markets is the inter-dealer trading on Nasdaq.

[10] Note that trades and quotes for Nasdaq-listed stocks originate mostly from the Nasdaq market, whereas many trades and quotes for NYSE-listed stocks reflect activity at a regional stock exchange or the NASD over-the-counter market. Bessembinder (1999) reports that approximately one-third of the trades for NYSE-listed stocks are executed off the NYSE. Because the recommended adjustment factor for Nasdaq volume that will neutralize the effect of inter-dealer trades is about 30% to 50% (see, e.g., Atkins and Dyl, 1997), our volume-counting scheme appears reasonable.

[11] During our sample time period, the TAQ database has data on 3,442 NYSE stocks. We exclude preferred stocks, warrants, and lower-class common stocks (e.g., class B and C common stocks) from the study sample. This leaves us a final sample of 2,912 stocks. There are more than 22 million trades and 42 million quotes in our study sample.

Table 1

Descriptive statistics for 460 matching pairs of Nasdaq-listed and NYSE-listed stocks

We match each stock in the Nasdaq sample with its NYSE counterpart based on the market value of equity (MVE). We first calculate the following match score (MS) for each Nasdaq stock in our sample against each of the 2,912 NYSE stocks in the TAQ database: $MS = [(MVE^N - MVE^Y)/(MVE^N + MVE^Y)/2]^2$, where MVE represents the market value of equity on January 31, 1998 and the superscripts, N and Y, refer to Nasdaq and NYSE, respectively. Then, for each Nasdaq stock, we pick the NYSE stock with the smallest score. We drop NYSE-Nasdaq pairs from the study sample if their share prices differ by more than $60. This procedure results in 460 pairs of Nasdaq and NYSE stocks. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices.

				Percentile				
Variable	Exchange	Mean	Standard Deviation	Min	25	50	75	Max
Share	Nasdaq	28.81	17.38	1.37	14.76	25.31	40.52	98.69
Price ($)	NYSE	28.98	17.21	1.94	25.79	25.79	37.58	118.58
Number	Nasdaq	21,105	28,708	437	5,727	10,870	24,528	263,952
of Trades	NYSE	4,234	4,161	173	1,445	2,903	5,568	34,869
Trade	Nasdaq	40,367	26,493	3,441	20,464	35,525	55,082	207,165
Size ($)	NYSE	40,048	29,234	4,720	18,997	32,332	51,779	202,187
Return	Nasdaq	0.0340	0.0174	0.0008	0.0230	0.0301	0.0402	0.1472
Volatility	NYSE	0.0154	0.0083	0.0020	0.0103	0.0144	0.0185	0.0791
Market	Nasdaq	1,143	1,599	22	278	633	1,290	12,915
Value of Equity ($millions)	NYSE	1,147	1,599	22	283	631	1,298	12,922

where MVE represents the market value of equity on January 31, 1998, and the superscripts, N and Y, refer to Nasdaq and NYSE, respectively. Then, for each Nasdaq stock, we pick the NYSE stock with the smallest score. We drop NYSE–Nasdaq pairs from the study sample if their share prices differ by more than $60. This procedure results in 460 pairs of Nasdaq and NYSE stocks.

We report summary statistics of our matched sample in Table 1. The average market value of equity for the Nasdaq sample ($1,143 million) is similar to the corresponding figure ($1,147 million) for the NYSE sample. The average price of our Nasdaq sample is $28.81, and the corresponding figure for the NYSE sample is $28.98. The average number of transactions and trade size for the Nasdaq sample are 21,105 and $40,367, respectively, and the corresponding figures for the NYSE sample are 4,234 and $40,048. The mean values of the standard deviation of daily returns for our Nasdaq and NYSE stocks are 0.0340 and 0.0154, respectively. Overall, our matching samples of Nasdaq and NYSE stocks are similar in price, trade size, and market capitalization but differ in return volatility and the number of trades. These are similar to sample characteristics in Bessembinder (1999).

3. Measures of trading costs and depths

We use three measures of trading costs in this study: quoted spread, effective spread, and realized spread.[12] The quoted spread is calculated as

$$\text{Quoted spread}_{it} = (A_{it} - B_{it})/M_{it} \tag{2}$$

where A_{it} is the posted ask price for stock i at time t, B_{it} is the posted bid price for stock i at time t, and M_{it} is the mean of A_{it} and B_{it}.

To more accurately measure trading costs when trades occur at prices inside the posted bid and ask quotes, we calculate the effective spread using the following formula:

$$\text{Effective spread}_{it} = 2D_{it}(P_{it} - M_{it})/M_{it} \tag{3}$$

where P_{it} is the transaction price for security i at time t, M_{it} is the midpoint of the most recently posted bid and ask quotes for security i, and D_{it} is a binary variable that equals 1 for customer buy orders and –1 for customer sell orders.[13] The effective spread measures the actual execution cost paid by the trader.

We calculate the realized spread using the following formula:

$$\text{Realized spread}_{it} = 2D_{it}(P_{it} - P_{it+30})/M_{it} \tag{4}$$

where P_{it+30} denotes the first transaction price observed at least 30 minutes after the trade for which the realized spread is measured and the other variables are the same as defined above. The realized spread measures the average price reversal after a trade (or market-making revenue net of losses to better informed traders). For each stock, we calculate the time-weighted quoted spread and traded-weighted effective and realized spreads using all the time-series observations during the three-month study period.

For each NYSE stock, we calculate the time-weighted average depth during the study period using data from the TAQ. The Nasdaq quotes in the TAQ database contain only the BBO for Nasdaq National Market System issues. For stocks with more than one market maker, the TAQ database reports only the depth of the market maker who quotes the largest size at the BBO. For this reason, the size field for Nasdaq quotes in the TAQ database is not representative of the market depth. To correctly measure the aggregate depth for each Nasdaq stock, we acquire the market-maker quote data from Nasdaq, which include the spread and depth quotes of each and every market maker. To obtain the aggregate depth, we first sum the depth at each BBO across

[12] A large number of quote updates for NYSE-listed stocks originate from off the NYSE. As Blume and Goldstein (1997) show, however, quotes that originate from off the NYSE only occasionally better NYSE quotes. Hence, we use only NYSE quotes in our study.

[13] We estimate D_{it} using the algorithm in Lee and Ready (1991).

market makers. We then calculate the time-weighted average of this aggregate depth for each Nasdaq stock during the three-month period.[14]

4. Comparison of spreads and depths between Nasdaq and NYSE stocks

In Table 2 we show the average quoted, effective, and realized spreads for our entire sample of Nasdaq and NYSE stocks and for each quartile based on share price, number of trades, trade size, return volatility, and market capitalization. For the whole sample, the average Nasdaq-quoted spread (0.9540%) is about 26% larger than the average NYSE-quoted spread (0.7563%). We find that quoted spreads of Nasdaq-listed stocks are wider than those of NYSE-listed stocks across all quartiles of share price, number of trades, trade size, return volatility, and market capitalization. The results of paired comparison *t*-tests show that the differences are statistically significant in most cases. Similarly, we find that Nasdaq-listed stocks have wider effective spreads than NYSE-listed stocks. The average effective spread for Nasdaq stocks (0.7522%) is about 32% larger than the average effective spread for NYSE stocks (0.5687%). We find similar results for the realized spread.

In Table 3 we report the average quoted depth for our entire sample of Nasdaq and NYSE stocks and for each stock attribute quartile. The results show that the quoted depth of Nasdaq-listed stocks is significantly smaller than the quoted depth of NYSE-listed stocks. The average depth of Nasdaq-listed stocks (4,339 shares) is only about 42% of the average depth of NYSE-listed stocks (10,388 shares).[15] We observe a similar pattern across all quartiles of share price, number of trades, trade size, return volatility, and market capitalization. The results of paired comparison *t*-tests show that the differences are all statistically significant.

Although the above results indicate that traders are likely to pay greater execution costs on Nasdaq, it is possible that the observed differences in spreads and depths between Nasdaq and NYSE stocks are due to differences in their attributes. Indeed, when we regress the spread against the stock attributes, the results (see Table 4) show that both Nasdaq and NYSE spreads are strongly related to the five stock attributes. All three measures of trading costs (i.e., the quoted, effective, and realized spreads) are negatively related to share price, number of trades, trade size, and market capitalization and positively related to return volatility. These variables explain about 85% to 90% of the cross-sectional variation in NYSE spreads and about 80% to 82% of the variation in Nasdaq spreads. When we perform similar regression analyses with

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[14] When we compare the average depth of our Nasdaq sample of stocks calculated from the TAQ database with the corresponding figure calculated from the market maker quote data, we find that the former is significantly (about 50%) less than the latter.

[15] We obtain similar results from depths measured in dollars because our Nasdaq and NYSE samples have very similar average share prices.

the depth, we find that the depth is also significantly related to these stock attributes (see Table 5).

To determine whether the differential stock attributes between Nasdaq and NYSE stocks can explain the difference between NYSE and Nasdaq spreads, we estimate the following regression model using data for our paired sample of 460 Nasdaq and NYSE stocks:

$$\text{Spread}^{\text{N}} - \text{Spread}^{\text{Y}} = \alpha_0 + \sum \alpha_{\text{i}}\left(X_i^{\text{N}} - X_i^{\text{Y}}\right) + \varepsilon \quad (5)$$

where N and Y refer to Nasdaq and NYSE, respectively, X_i ($i = 1$ to 5) represents one of the five stock attributes (share price, number of trades, trade size, return volatility, and market capitalization), Σ denotes the summation over $i = 1$ to 5, αs are the regression coefficients, and ε is the error term.

The results (see Table 4) show that there are significant differences in spreads between our Nasdaq and NYSE stocks, even after controlling for differences in their attributes. The highly significant and positive intercepts in all three regressions suggest that the average quoted, effective, and realized spreads of Nasdaq stocks are larger than those of NYSE stocks. When we replicate our analysis with the quoted depth (see Table 5), we find that the intercept is highly significant and negative, indicating that the average quoted depth of Nasdaq stocks is smaller than the average quoted depth of NYSE stocks. The differential spreads (depth) cannot be attributed to differences in stock attributes because we control for these differences in our regression. These results suggest that the differences in spreads and depths between Nasdaq and NYSE stocks presented in Table 2 and Table 3 are not due to differences in the stock attributes.

Note that the estimates of α_0 in Table 4 are all larger than the observed spread differences between the two groups of stocks shown in Table 2. For example, the estimated intercepts are 0.0032, 0.0028, and 0.0038, respectively, when we estimate the above regression model using the quoted, effective, and realized spreads, which are larger than the observed differences (i.e., 0.001977, 0.001835, and 0.003293) in spreads shown in Table 2. These results suggest that the actual differences in spreads between Nasdaq and NYSE stocks are much larger than those reported in Table 2, once we consider the differences in stocks attributes between the two groups of stocks. One possible explanation for this result is that the average number of trades for our Nasdaq stocks is much greater than the corresponding figure for their size-matched NYSE counterparts. Because the spread is strongly and inversely related to the number of trades, the differential spreads between Nasdaq and NYSE stocks reported in Table 2 understate their true differences (i.e., the differences that account for the difference in the number of trades).

On the whole, our empirical findings indicate that Nasdaq stocks have, on average, larger spreads and smaller depths than comparable stocks on the NYSE. Hence, despite legal actions taken against Nasdaq dealers and a series of subsequent market reforms, including the new order-handling rules and the tick size reduction, the overall level of liquidity on Nasdaq is still significantly lower than the level of liquidity

Table 2

Comparison of spreads between Nasdaq stocks and NYSE stocks

This table reports the average Nasdaq and NYSE spreads for our whole sample and for each quartile based on share price, number of trades, trade size, return volatility, and market capitalization. The quoted spread is calculated as $(A_{it} - B_{it})/M_{it}$, where A_{it} is the posted ask price for stock *i* at time *t*, B_{it} is the posted bid price for stock *i* at time *t*, and M_{it} is the mean of A_{it} and B_{it}. The effective spread measures the percentage execution costs actually paid by the trader. The realized spread measures price reversals after trades. The table also reports the results of paired comparison t-tests for Nasdaq spread and NYSE spread. The tests show whether the mean difference is significantly different from zero. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices. All numbers are in percentages (i.e., 0.015196 is reported as 1.5196). Q1 is the smallest and Q4 is the largest.

		Quoted Spread				Effective Spread				Realized Spread			
Quartile Based on		Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat	Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat	Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat
Share Price	Q1	1.5196	1.2703	0.2493	2.70**	1.2146	0.9927	0.2219	3.11**	1.1627	0.7182	0.4444	7.61**
	Q2	0.8984	0.7984	0.1000	2.38*	0.7029	0.5929	0.1100	3.36**	0.6866	0.4029	0.2837	10.34**
	Q3	0.7773	0.5786	0.1987	6.22**	0.6046	0.4195	0.1852	7.98**	0.5866	0.2818	0.3048	14.84**
	Q4	0.6209	0.3781	0.2428	7.87*	0.4867	0.2698	0.2169	9.05**	0.4703	0.1860	0.2843	13.50**
Number of Trades	Q1	1.3953	1.1213	0.2740	3.38**	1.1043	0.8458	0.2585	4.02**	1.0271	0.5679	0.4592	8.36**
	Q2	1.0626	0.8394	0.2232	3.64**	0.8224	0.6308	0.1917	4.09**	0.7967	0.4440	0.3527	8.80**
	Q3	0.8079	0.6311	0.1768	3.24**	0.6364	0.4730	0.1634	3.67**	0.6272	0.3428	0.2844	7.65**
	Q4	0.5503	0.4336	0.1167	3.46**	0.4457	0.3252	0.1205	4.15**	0.4552	0.2342	0.2210	7.99**
Trade Size	Q1	1.5367	1.1788	0.3579	3.94**	1.2320	0.9059	0.3261	4.59**	1.1812	0.6515	0.5297	9.08**
	Q2	0.9100	0.8164	0.0936	1.91	0.7106	0.6134	0.0972	2.60*	0.6886	0.4201	0.2685	9.28**
	Q3	0.7112	0.6070	0.1042	2.93**	0.5578	0.4465	0.1114	3.98**	0.5440	0.3053	0.2387	10.20**
	Q4	0.6583	0.4232	0.2351	6.72**	0.5084	0.3091	0.1993	7.59**	0.4923	0.2119	0.2803	12.13**

(*continued*)

Table 2 (*continued*)

Quartile Based on		Quoted Spread				Effective Spread				Realized Spread			
		Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat	Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat	Nasdaq Spread	NYSE Spread	Nasdaq-NYSE	*t*-stat
Return	Q1	0.7213	0.7066	0.0146	0.38	0.5713	0.5610	0.0103	0.33	0.5435	0.4424	0.1011	3.52**
Volatility	Q2	0.9210	0.6406	0.2804	5.06**	0.7199	0.4668	0.2531	5.84**	0.6914	0.3167	0.3747	10.04**
	Q3	0.9742	0.6610	0.3132	4.73**	0.7722	0.4870	0.2852	5.53**	0.7431	0.3306	0.4124	9.40**
	Q4	1.1997	1.0171	0.1825	1.88	0.9454	0.7600	0.1855	2.41*	0.9282	0.4992	0.4290	6.91**
Market Value	Q1	1.6263	1.2662	0.3601	4.01**	1.2891	0.9633	0.3258	4.65**	1.2266	0.6579	0.5688	9.93**
of Equity	Q2	0.9683	0.7379	0.2304	7.62**	0.7535	0.5592	0.1943	8.30**	0.7312	0.3978	0.3335	16.08**
	Q3	0.7377	0.6135	0.1242	3.88**	0.5805	0.4549	0.1256	4.91**	0.5648	0.3276	0.2372	10.55**
	Q4	0.4839	0.4078	0.0761	3.21**	0.3857	0.2974	0.0883	4.77**	0.3835	0.2057	0.1778	11.66**
Whole Sample		0.9540	0.7563	0.1977	5.58**	0.7522	0.5687	0.1835	6.58**	0.7265	0.3972	0.3293	14.03**

** Indicates statistical significance at the 0.01 level.
* Indicates statistical significance at the 0.05 level.

Table 3

Comparison of depths between Nasdaq stocks and NYSE stocks

We calculate the time-weighted average depth using all the time-series observations during the three-month study period. We report the results of paired comparison t-tests for the equality of depths between Nasdaq and NYSE stocks. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices. Q1 is the smallest and Q4 is the largest.

		Depths			
Quartile Based on	Quartile	Nasdaq Quote	NYSE Quote	Nasdaq - NYSE	*t*-stat
Share Price	Q1	5,680	23,845	−18,165	5.69**
	Q2	4,538	7,029	−2,492	4.55**
	Q3	3,621	5,600	−1,979	5.11**
	Q4	3,518	5,076	−1,559	4.59**
Number of Trades	Q1	3,335	7,325	−3,991	5.03**
	Q2	3,873	11,233	−7,361	3.09**
	Q3	4,255	11,354	−7,100	3.76**
	Q4	5,895	11,638	−5,744	3.38**
Trade Size	Q1	5,288	15,703	−10,415	3.95**
	Q2	4,570	10,629	−6,059	3.14**
	Q3	3,972	7,426	−3,453	2.77**
	Q4	3,526	7,793	−4,267	7.97**
Return Volatility	Q1	3,767	21,033	−17,266	5.70**
	Q2	4,086	5,580	−1,494	3.04**
	Q3	4,640	6,325	−1,685	3.66**
	Q4	4,862	8,613	−3,750	2.72**
Market Value of Equity	Q1	4,571	9,432	−4,861	4.13**
	Q2	3,936	12,956	−9,020	3.62**
	Q3	4,268	10,754	−6,485	3.03**
	Q4	4,581	8,409	−3,828	4.80**
Whole Sample		4,339	10,388	−6,049	6.76**

** Indicates statistical significance at the 0.01 level.

on the NYSE. Our analysis suggests that it is unlikely that the results are driven by differential characteristics between the two groups of stocks. Rather, the results are likely driven by institutional differences and/or market structure differences.

The wider spread on Nasdaq could indicate that limit-order traders on Nasdaq play less significant roles in establishing spread quotes compared to limit-order traders on the NYSE. In addition, as pointed out by Huang and Stoll (1996) and others, there could be several structural factors that deter price improvement on Nasdaq. Internalization is one likely source of the lower price improvement rate on Nasdaq. To the extent that dealers at broker-dealer firms do not have to compete for the order flow using their own quotes, there is little incentive for them to offer price improvement. Competition is also limited by the practice of preferencing customer order flow. If a large fraction of the retail order flow is preferenced, there is little incentive for a dealer to offer price improvement.[16]

5. Quote clustering and its impact on spreads

5.1. Quote clustering

Christie and Schultz (1994) and Barclay (1997) show that the frequency of even-eighth quotes on Nasdaq is much higher than the corresponding figure on the NYSE. Based on this evidence, they suggest that there exists implicit collusion among Nasdaq dealers. Christie, Harris, and Schultz (1994), Bessembinder (1997), and Christie and Schultz (1999) provide additional evidence that is consistent with collusive behavior. Others argue that the higher frequency of even-eighth quotes does not necessarily imply covert collusion among market makers. For example, Grossman, Miller, Fischel, Cone, and Ross (1997) suggest that the less-frequent use of odd-eighth quotes among Nasdaq dealers could be attributed to the natural clustering of price in competitive financial markets.[17] They suggest that market participants use a coarse price grid as protection against informed traders, as compensation for increased inventory risk, and to minimize the cost of negotiation. In a similar vein, Furbush (1995), Kleidon and Willig (1995), Laux (1995), Godek (1996), and Huang and Stoll (1996) suggest that collusion is implausible in a market with many competitors and easy entry.

In this study, we compare the extent of quote clustering between Nasdaq and NYSE stocks using data after the implementation of the new SEC order-handling rules and the new minimum tick size. The new SEC rules require that limit-order quotes be displayed in the Nasdaq BBO when they improve market-maker quotes and allow the public access to superior quotes in ECNs. These rule changes, together with the reduction in tick size from $1/8 to $1/16 on both the NYSE and Nasdaq, offer an opportunity to reevaluate the quotation behavior of liquidity providers.

We report in Table 6 the proportion of Nasdaq quotes in each quote increment. The results show that the proportion of even-sixteenth quotes (72%) is significantly larger than that of odd-sixteenth quotes. The proportion of even-eighth quotes among those quotes in eighths is only 55%, which is significantly smaller than the corresponding figure (84%) reported in Huang and Stoll (1996). The proportion of even-fourths among those quotes in quarters is slightly larger than 53%. These results suggest that the avoidance of odd-eighth quotes by market makers reported in previous studies has largely been replaced by the avoidance of odd-sixteenths after the

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[16] Other likely sources of the wider spreads on Nasdaq are commissions and the existence of alternative dealer quote dissemination systems. See Huang and Stoll (1996) for a detailed discussion of these issues.

[17] The stock price clustering was first noted in Harris (1991).

Table 4

Effects of stock characteristics on spreads

We regress measures of execution costs against the five stock attributes using our sample of Nasdaq stocks and the matched sample of NYSE stocks. We use three measures of execution costs: the quoted spread, effective spread, and realized spread. The quoted spread is calculated as $(A_{it} - B_{it})/M_{it}$, where A_{it} is the posted ask price for stock i at time t, B_{it} is the posted bid price for stock i at time t, and M_{it} is the mean of A_{it} and B_{it}. The effective spread measures the execution cost actually paid by the trader. The realized spread measures price reversals after trades. For each stock, we calculate the average quoted, effective, and realized spreads using all the time-series observations during the three-month study period and then use these averages in the regressions. The results from these regressions help us assess whether the five stock attributes are important determinants of the cross-sectional variation in spreads for our sample of stocks. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices. To determine whether the differential stock attributes between Nasdaq and NYSE stocks can explain the difference between NYSE and Nasdaq spreads, we estimate the following regression model using data for our paired sample of 460 Nasdaq and NYSE stocks: $\text{Spread}^N - \text{Spread}^Y = \alpha_0 + \Sigma\alpha_i(X_i^N - X_i^Y) + \varepsilon$; where N and Y refer to Nasdaq and NYSE, respectively, X_i ($i = 1$to 5) represents one of the five stock attributes (share price, number of trades, trade size, return volatility, and market capitalization), Σ denotes the summation over $i = 1$ to 5, αs are the regression coefficients, and ε is the error term. Absolute values of t-statistics are reported in parentheses.

Independent Variable	Quoted Spread			Effective Spread			Realized Spread		
	Nasdaq	NYSE	Nasdaq-NYSE	Nasdaq	NYSE	Nasdaq - NYSE	Nasdaq	NYSE	Nasdaq - NYSE
Intercept	0.0604	0.0224	0.0032	0.0486	0.0156	0.0028	0.0436	0.0099	0.0038
	(20.67**)	(11.63**)	(11.60**)	(20.35**)	(12.77**)	(13.32**)	(20.31**)	(11.50**)	(20.50**)
1/(Share Price)	0.0277	0.0722	0.0389	0.0233	0.0609	0.0335	0.0226	0.0471	0.0323
	(10.09**)	(25.90**)	(12.62**)	(10.41**)	(34.48**)	(14.31**)	(11.21**)	(37.64**)	(15.31**)
log (Number of Trades)	−0.0025	−0.0015	−0.0018	−0.0019	−0.0010	−0.0013	−0.0017	−0.0005	−0.0009
	(15.95**)	(9.23**)	(11.03**)	(15.01**)	(10.12**)	(10.50**)	(14.94**)	(6.95**)	(8.54**)
log (Trade Size)	−0.0019	−0.0006	−0.0005	−0.0017	−0.0003	−0.0004	−0.0015	−0.0002	−0.0004
	(6.11**)	(2.71**)	(1.83)	(6.71**)	(2.34*)	(2.14*)	(6.72**)	(2.40*)	(2.24*)

(*continued*)

Table 4 (*continued*)

	Quoted Spread			Effective Spread			Realized Spread		
Independent Variable	Nasdaq	NYSE	Nasdaq-NYSE	Nasdaq	NYSE	Nasdaq - NYSE	Nasdaq	NYSE	Nasdaq - NYSE
Return Volatility	0.0402	0.1454	0.0561	0.0258	0.0919	0.0348	0.0337	0.0230	0.0299
	(4.60**)	(12.37**)	(5.63**)	(3.62**)	(12.32**)	(4.60**)	(5.25**)	(4.36**)	(4.38**)
log (Market Value	−0.0008	−0.0008	−0.0010	−0.0006	−0.0002	−0.0004	−0.0005	−0.0002	−0.0002
of Equity)	(4.36**)	(1.45)	(0.70)	(3.79**)	(2.24*)	(0.41)	(3.73**)	(2.51*)	(0.20)
F-value	407.75	537.90	75.24	371.73	830.13	86.68	423.51	812.07	94.12
Adjusted R^2	0.8159	0.8540	0.4471	0.8098	0.9003	0.4828	0.8215	0.8983	0.5036

** Indicates statistical significance at the 0.01 level.
* Indicates statistical significance at the 0.05 level.

Table 5

Effects of stock characteristics on depths

We regress the depth against the five stock attributes using our sample of Nasdaq stocks and the matched sample of NYSE stocks. For each stock, we calculate the average depth using all the time-series observations during the three-month study period and use this average in the regressions. The results from these regressions help us assess whether the five stock attributes are important determinants of the cross-sectional variation in depths for our sample of stocks. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices. To determine whether the differential stock attributes between Nasdaq and NYSE stocks can explain the difference between NYSE and Nasdaq depths, we estimate the following regression model using data for our paired sample of 460 Nasdaq and NYSE stocks: $\text{Depth}^{N} - \text{Depth}^{Y} = \alpha_0 + \Sigma\alpha_i\ (X_i^N - X_i^Y) + \varepsilon$; where N and Y refer to Nasdaq and NYSE, respectively, X_i (i = 1 to 5) represents one of the five stock attributes (share price, number of trades, trade size, return volatility, and market capitalization), Σ denotes the summation over i = 1 to 5, αs are the regression coefficients, and ε is the error term. Absolute values of *t*-statistics are reported in parentheses.

Independent Variables	Nasdaq	NYSE	Nasdaq-NYSE
Intercept	−9,903	−37,405	−4,262
	(5.29**)	(2.78**)	(3.24**)
log (Share Price)	−2,730	−23,626	−15,674
	(11.90**)	(13.27**)	(10.07**)
log (Number of Trades)	837	3,469	1,064
	(9.81**)	(2.72**)	(1.34)
log (Trade Size)	846	5,769	3,308
	(3.70**)	(3.24**)	(2.19*)
Return Volatility	−8,182	−516,253	−212,554
	(1.75)	(5.58**)	(4.58**)
log (Market Value of Equity)	487	3,277	8,954
	(4.43**)	(2.47*)	(1.33)
F-value	106.60**	49.01**	33.24**
Adjusted R^2	0.5350	0.3434	0.2599

** Indicates statistical significance at the 0.01 level.
* Indicates statistical significance at the 0.05 level.

reduction in the minimum tick size. For our NYSE sample, we find that the proportion of even-sixteenth quotes (61%) is significantly larger than that of odd-sixteenth quotes, but the use of even quotes at larger grids is not as frequent as in the case of sixteenths.

One might argue that the prevalence of even-sixteenths over odd-sixteenths on both Nasdaq and the NYSE is due to deliberate attempts by market makers/specialists to widen their spreads. As shown by Chung, Van Ness, and Van Ness (1999), the majority of NYSE quotes reflect the interest of limit-order traders. Similarly, a significant portion of Nasdaq quotes could now reflect the interest of limit-order traders. Consequently, attributing more frequent even-sixteenth quotes on the NYSE and Nasdaq to specialist/dealer behavior could be fallacious. As suggested by numerous

Table 6

Distribution of Nasdaq and NYSE quotes by even- and odd-quotes

Panel A reports the percentage of Nasdaq and NYSE quotes in each quote increment. Panel B reports the proportion of even-quotes within each price grid.

	Nasdaq Quotes			NYSE Quotes		
Quote	Bid	Ask	Total	Bid	Ask	Total
Panel A: Proportion of quotes in each quote increment						
0/16	0.1124	0.1195	0.1159	0.0925	0.0961	0.0943
1/16	0.0405	0.0389	0.0397	0.0497	0.0479	0.0488
2/16	0.0797	0.0847	0.0822	0.0696	0.0700	0.0698
3/16	0.0316	0.0334	0.0325	0.0451	0.0490	0.0470
4/16	0.0890	0.0941	0.0915	0.0736	0.0773	0.0755
5/16	0.0335	0.0303	0.0319	0.0480	0.0468	0.0474
6/16	0.0781	0.0791	0.0786	0.0688	0.0666	0.0677
7/16	0.0336	0.0349	0.0343	0.0443	0.0483	0.0463
8/16	0.0957	0.1002	0.0979	0.0809	0.0777	0.0793
9/16	0.0345	0.1195	0.0335	0.0495	0.0961	0.0478
10/16	0.0785	0.0756	0.0770	0.0758	0.0699	0.0729
11/16	0.0338	0.0331	0.0335	0.0461	0.0494	0.0478
12/16	0.0940	0.0926	0.0933	0.0795	0.0765	0.0780
13/16	0.0361	0.0307	0.0334	0.0499	0.0450	0.0474
14/16	0.0874	0.0807	0.0841	0.0782	0.0721	0.0751
15/16	0.0415	0.0398	0.0407	0.0486	0.0615	0.0551
Panel B: Proportion of even-quotes within each price grid						
Proportion of even-16ths among 16ths	0.7148	0.7265	0.7206	0.6189	0.6060	0.6125
Proportion of even-8ths among 8ths	0.5420	0.5539	0.5481	0.5265	0.5379	0.5320
Proportion of even-4ths among Quarters	0.5308	0.5371	0.5343	0.5267	0.5290	0.5293

researchers,[18] the observed quote clustering on Nasdaq and the NYSE could also be driven by other reasons.

Several studies find a significant increase in the frequency of odd-eighth quotes on Nasdaq after the public disclosure of Christie and Schultz's (1994) findings.[19]

[18] See Doran, Lehn, and Shastri (1995), Furbush (1995), Kleidon and Willig (1995), Laux (1995), Godek (1996), Grossman, Miller, Fischel, Cone, and Ross (1997), and Huang and Stoll (1996).

[19] See Christie, Harris, and Schultz (1994), Bessembinder (1997), Christie and Schultz (1999), and Barclay, Christie, Harris, Kandel, and Schultz (1999).

Some researchers (e.g., Christie, Harris, and Schultz, 1994) have interpreted the finding as evidence that market makers stopped colluding due to pressures from the negative publicity and investigations by the Department of Justice and the SEC. Alternatively, it could reflect the attempts of noncollusive market makers to avoid being charged with collusion on the basis of mistaken interpretations of data. Indeed, Sherwood Securities, which settled the litigation by agreeing to pay a total of $9.2 million, maintained that it had not engaged in any improper conduct.

If one interprets the decrease in the use of even-eighth quotes as the manifestation of reduced dealer collusion, the prevalence of even-sixteenth quotes after the introduction of the new minimum tick size is puzzling. One could argue that market makers renewed their collusion by avoiding odd-sixteenths and thereby maintained bid-ask spreads at supracompetitive levels. This scenario does not appear to be plausible, given the negative publicity of Nasdaq collusion and the possible penalty for anticompetitive behavior.[20] These considerations suggest that the prevalence of even-sixteenth quotes (or the lack of odd-sixteenth quotes) might be driven by reasons other than collusion, such as natural clustering or investor habits.

5.2. Impact of quote clustering on spreads

Previous studies show that stocks with higher proportions of even quotes exhibit wider spreads.[21] In this section, we examine whether the same pattern exists after the 1997 SEC rule changes. We analyze how the quoted, effective, and realized spreads are related to the extent of quote clustering after we control for the effects of stock attributes on spreads. Specifically, we regress the quoted, effective, and realized spreads against the five stock attributes and obtain the residuals (residual spreads) from each regression. We then estimate the following four regression models for each of the three spread measures (i.e., the quoted, effective, and realized spreads):

$$\text{Residual spread} = \alpha_0 + \alpha_1 \text{QC}^{1/16} + \varepsilon \quad (6)$$

$$\text{Residual spread} = \alpha_0 + \alpha_1 \text{QC}^{1/8} + \varepsilon \quad (7)$$

$$\text{Residual spread} = \alpha_0 + \alpha_1 \text{QC}^{1/4} + \varepsilon \quad (8)$$

$$\text{Residual spread} = \alpha_0 + \alpha_1 \text{QC}^{1/16} + \alpha_2 \text{QC}^{1/8} + \alpha_3 \text{QC}^{1/4} + \varepsilon \quad (9)$$

[20] Sherwood Securities was the first defendant to settle litigation by agreeing to pay a total of $9.2 million on April 10, 1997. Kidder Peabody agreed to an out-of-court settlement of $14.1 million, followed by Herzog, Heine, Geduld Inc., which settled for $30.6 million on June 8, 1997. A global settlement ($900 million) that included all but one of the remaining 31 defendants was reached on December 24, 1997. The sum of all payments, including interest, totaled $1.027 billion.

[21] See, for example, Christie and Schultz (1994), Godek (1996), and Barclay (1997).

where $QC^{1/16}$ is the proportion of even-sixteenths quotes among sixteenths, $QC^{1/8}$ is the proportion of even-eighths among eighths, and $QC^{1/4}$ is the proportion of even-fourths among quarters.

Panel A of Table 7 shows the results for the Nasdaq sample, and panel B shows the results for the NYSE stocks. For each spread measure, the first three columns show the results when we regress the residual spread against each of the three quote-clustering measures, and the fourth column shows the results when all three quote-clustering measures are simultaneously included in the regression.

The results show that the residual (quoted, effective, and realized) spreads of Nasdaq stocks are all positively and significantly related to the proportions of even-sixteenths and even-eighths. The positive correlation between quoted spreads and the degree of quote clustering is consistent with the finding of Christie and Schultz (1994). For the NYSE sample, the residual quoted spread is positively and significantly related to the proportions of both even-sixteenths and even-eighths, although the significance of the even-eighths quote clustering vanishes when all three quote-clustering measures are included in the regression. We find similar results for the residual effective spreads. In the realized spread regression, we find that the proportion of even-sixteenths and the proportion of even-eighths are both significant, separately as well as simultaneously.

Note that the proportion of even-sixteenths alone explains 16%, 20%, and 11%, respectively, of the cross-sectional variation in the residual quoted, effective, and realized spreads of NYSE stocks. In contrast, the proportion of even-eighths explains only 1%, 2%, and 4%, respectively, of the cross-sectional variation on the residual quoted, effective, and realized spreads. For the Nasdaq sample, we find that the proportion of even-sixteenths (eighths) explains about 8% of the cross-sectional variation in the residual quoted, effective, and realized spreads.

Bessembinder (1999) reports that there is no significant relation between realized spreads and the proportion of even-eighth quotes for both Nasdaq and NYSE stocks. Bessembinder (1999, p. 404) concludes that "trade execution costs on Nasdaq in late 1997 are no longer significantly explained by a tendency for liquidity providers to avoid odd-eighth quotations." The study also concludes that "odd-sixteenth avoidance has little relevance for explaining post-reform Nasdaq trading costs." These results differ from the finding of the present study that stocks with higher proportions of even-eighth and even-sixteenth quotes have wider quoted, effective, and realized spreads on both the NYSE and Nasdaq.[22]

Although we find a positive effect of quote clustering on the spreads of NYSE and Nasdaq stocks, what triggers such an effect is not so evident. In Christie and Schultz (1994), the high frequency of even-eighth quotes is claimed to be a reflection of dealers' collusive behavior to maintain supracompetitive spreads. Hence, it is the

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[22] When we replicate Table 5 in (Bessembinder 1999, p. 402) with our data, we find that the quoted and realized spreads are significantly and negatively related to the proportion of odd-sixteenth quotes for both NYSE and Nasdaq samples.

Table 7

Effects of quote clustering on spreads

We regress the quoted, effective, and realized spreads against the five stock attributes and obtain the residuals (residual spreads) from each regression. We then estimate the following four regression models for each of the three spread measures (i.e., the quoted, effective, and realized spreads): Residual spread $= \alpha_0 + \alpha_1 QC^{1/16} + \varepsilon$; Residual spread $= \alpha_0 + \alpha_1 QC^{1/8} + \varepsilon$; Residual spread $= \alpha_0 + \alpha_1 QC^{1/4} + \varepsilon$; Residual spread $= \alpha_0 + \alpha_1 QC^{1/16} + \alpha_2 QC^{1/8} + \alpha_3 QC^{1/4} + \varepsilon$; where $QC^{1/16}$ is the proportion of even-sixteenths among sixteenths, $QC^{1/8}$ is the proportion of even-eighths among eighths, and $QC^{1/4}$ is the proportion of even-fourths among quarters. Absolute values of *t*-statistics are reported in parentheses.

	Quoted Spread				Effective Spread				Realized Spread			
Panel A: Nasdaq sample												
Intercept	−0.0044	−0.0078	−0.0003	−0.0051	−0.0038	−0.0065	−0.0002	−0.0042	−0.0034	−0.0062	−0.0005	−0.0042
	(6.13**)	(6.18**)	(0.17)	(2.97**)	(6.48**)	(6.27**)	(0.19)	(3.02**)	(6.34**)	(6.66**)	(0.39)	(3.37**)
$QC^{1/16}$	0.0062			0.0032	0.0053			0.0030	0.0047			0.0022
	(6.20**)			(2.20*)	(6.56**)			(2.61**)	(6.42**)			(2.06*)
$QC^{1/8}$		0.0143		0.0107		0.0118		0.0081		0.0112		0.0088
		(6.21**)		(3.04**)		(6.29**)	0.0005	(2.82**)		(6.69**)		(3.44**)
$QC^{1/4}$			0.0005	−0.0056				−0.0045			0.0008	−0.0040
			(0.17)	(1.80)			(0.19)	(1.75)			(0.39)	(1.75)
F-value	38.39**	38.50**	0.03	16.28**	43.00**	39.60**	0.04	17.39**	41.15**	44.69**	0.15	18.05**
Adjusted R^2	0.0753	0.0755	0.0021	0.0908	0.0838	0.0776	0.0021	0.0967	0.0804	0.0869	0.0018	0.1002
Panel B: NYSE sample												
Intercept	−0.0067	−0.0024	0.0004	−0.0062	−0.0047	−0.0019	0.0001	−0.0047	−0.0024	−0.0017	−0.0001	−0.0030
	(9.52**)	(2.70**)	(0.75)	(6.02**)	(10.81**)	(3.38**)	(0.32)	(7.32**)	(7.38**)	(4.30**)	(0.24)	(6.39**)
$QC^{1/16}$	0.0109			0.0109	0.0077			0.0076	0.0039			0.0035
	(9.59**)			(9.14**)	(10.88**)			(10.23**)	(7.43**)			(6.39**)
$QC^{1/8}$		0.0045		0.0002		0.0035		0.0005		0.0031		0.0017
		(2.71**)		(0.125)		(3.40**)		(0.54)		(4.32**)		(2.35*)
$QC^{1/4}$			−0.0008	−0.0012			−0.0002	−0.0005			0.0001	−0.0001
			(0.76)	(1.24)			(0.32)	(0.85)			(0.24)	(0.22)
F-value	91.94**	7.35*	0.58	31.13**	118.45**	11.53**	0.11	39.71**	55.15**	18.65**	0.06	20.37**
Adjusted R^2	0.1654	0.0136	−0.0009	0.1645	0.2037	0.0224	−0.0020	0.2019	0.1055	0.0370	−0.0021	0.1124

** Indicates statistical significance at the 0.05 level.
* Indicates statistical significance at the 0.01 level.

dealers' desire to maintain larger spreads that *causes* quote clustering. Alternatively, the positive correlation between spreads and quote clustering could largely be an unintended outcome of investor preference toward coarse quotes discussed earlier. For example, if all the market makers and limit-order traders use only even-sixteenth quotes, the quoted spread will be at least $1/8. On the other hand, if these liquidity providers do not exhibit such a preference and thus each quote increment is equally likely, the minimum spread is $1/16. Hence, the observed spread is likely to be positively related to the proportion of even-sixteenths, regardless of the underlying reasons.

6. Sensitivity analyses

As noted in Section 2 (see also Table 1), our matching samples of Nasdaq and NYSE stocks are similar in price, trade size, and market capitalization but differ considerably in return volatility and the number of trades. For example, the mean (median) value of return volatility for our Nasdaq sample is about 2.2 (2.1) times the corresponding figures for the NYSE sample. Note that return volatility at the 25th percentile in the Nasdaq sample is nearly 25% larger than return volatility at the 75th percentile in the NYSE sample. Similarly, the two groups of stocks are dramatically different in their trading frequencies. As a result, the observed differences in trading cost and quote clustering between the two samples could be due to their differential attributes. In this section, we examine this possibility by replicating our analyses using a sample of Nasdaq and NYSE stocks that are matched by the five stock attributes—share price, number of trades, trade size, return volatility, and market capitalization.

To obtain the matching sample of Nasdaq and NYSE stocks, we first calculate the composite match score (CMS) for each Nasdaq stock in our sample against each of 2,912 NYSE stocks in the TAQ database: $\mathrm{CMS} = \Sigma[(X_k^N - X_k^Y)/\{(X_k^N + X_k^Y)/2\}]^2$, where X_k represents one of the five stock attributes and the superscripts, N and Y, refer to Nasdaq and NYSE, respectively. Then, for each Nasdaq stock, we pick the NYSE stock with the smallest score.

We find that the average market values of equity for the Nasdaq and NYSE samples are $1,449 million and $1,687 million, respectively. The average price of our Nasdaq sample is $33.41, and the corresponding figure for the NYSE sample is $33.49. The average number of trades and trade size for the Nasdaq sample are 10,922 and $47,096, respectively, and the corresponding figures are 7,748 and $47,109 for the NYSE sample. The mean values of return volatility for our Nasdaq and NYSE stocks are 0.0264 and 0.0216, respectively. Overall, our matching samples of Nasdaq and NYSE stocks are similar not only in share price, trade size, and market capitalization but also in return volatility and the number of trades.

When we replicate Table 2 through Table 7 using these newly matched Nasdaq–NYSE stocks, however, the results are qualitatively similar to those from our original study sample.[23] The average quoted, effective, and realized spreads for the Nasdaq sample are all significantly greater than the corresponding figures for the NYSE sample. We also find that NYSE stocks have much larger quoted depths than Nasdaq counterparts. The Nasdaq sample exhibits a considerably higher proportion of even-sixteenth quotes than the NYSE sample, but the differences in the proportion of even-eighths and even quarters between the two samples are relatively small. Finally, we find that both Nasdaq and NYSE spreads are significantly and positively related to the proportion of even quotes. Hence, we conclude that our results are quite robust and not sensitive to different matching methods.

To further assess the sensitivity of our results to different empirical methodologies, we estimate the following regression models using data on our study sample of Nasdaq stocks and the entire population of NYSE stocks available from the TAQ:

$$\begin{aligned}\text{Spread} = \alpha_0 &+ \alpha_1\text{DUM}^\text{N} + \alpha_2\text{QC}^{1/16} \times \text{DUM}^\text{Y} + \alpha_3\text{QC}^{1/8} \times \text{DUM}^\text{Y} \\ &+ \alpha_4\text{QC}^{1/4} \times \text{DUM}^\text{Y} + \alpha_5\text{QC}^{1/16} \times \text{DUM}^\text{N} + \alpha_6\text{QC}^{1/8} \times \text{DUM}^\text{N} \\ &+ \alpha_7 QC^{1/4} \times \text{DUM}^\text{N} + \alpha_8 1/(\text{Share Price}) + \alpha_9 \log(\text{Trade Size}) \\ &+ \alpha_{10}\,\text{Return Volatility} + \alpha_{11} \log(\text{Market Value of Equity}) \\ &+ \alpha_{12} \log(\text{Number of Trades}) \times \text{DUM}^\text{Y} \\ &+ \alpha_{13} \log(\text{Number of Trades}) \times \text{DUM}^\text{N} + \varepsilon \end{aligned} \quad (10)$$

$$\begin{aligned}\text{Depth} = \beta_0 &+ \beta_1\text{DUM}^\text{N} + \beta_2 \log(\text{Share Price}) + \beta_3 \log(\text{Trade Size}) \\ &+ \beta_4\,\text{Return Volatility} + \beta_5 \log(\text{Market Value of Equity}) \\ &+ \beta_6 \log(\text{Number of Trades}) \times \text{DUM}^\text{Y} \\ &+ \beta_7 \log(\text{Number of Trades}) \times \text{DUM}^\text{N} + \varepsilon \end{aligned} \quad (11)$$

where DUM^N equals one for Nasdaq stocks and zero otherwise, DUM^Y equals one for NYSE stocks and zero otherwise, and all other variables are the same as previously defined. If the average spread of Nasdaq stocks is significantly greater than the average spread of NYSE stocks after controlling for differences in quote clustering and stock attributes, we expect α_1 to be significant and positive. Similarly, if the average depth of Nasdaq stocks is significantly smaller than the average depth of NYSE stocks, we expect β_1 to be negative. The effects of quote clustering on NYSE and Nasdaq spreads are measured by α_2 through α_7. We allow a separate slope coefficient on number of trades for each market to reflect different volume-counting methods between the two markets.

We report the results in Table 8. The results show that the estimate of α_1 is significantly positive and the estimate of β_1 is significantly negative, respectively, confirming our earlier findings that Nasdaq stocks exhibit wider spreads and smaller depths than NYSE stocks. Consistent with our earlier finding, the results also show that the proportion of even-sixteenths has a significant and positive effect on NYSE

[23] For space consideration, we do not include these results in the paper. The results are available from the authors on request.

Table 8

Sensitivity analyses

To further assess the sensitivity of our results to different empirical methodologies, we estimate the following regression models using data on our study sample of Nasdaq stocks and the entire population of NYSE stocks available from the TAQ:

$$\begin{aligned}\text{Spread} = \alpha_0 &+ \alpha_1\ \text{DUM}^N + \alpha_2\ \text{QC}^{1/16} \times \text{DUM}^Y + \alpha_3\text{QC}^{1/8} \times \text{DUM}^Y + \alpha_4\text{QC}^{1/4} \times \text{DUM}^Y \\ &+ \alpha_5\ \text{QC}^{1/16} \times \text{DUM}^N + \alpha_6\ \text{QC}^{1/8} \times \text{DUM}^N + \alpha_7\ \text{QC}^{1/4} \times \text{DUM}^N + \alpha_8\ 1/\ (\text{Share Price}) \\ &+ \alpha_9 \log(\text{Trade Size}) + \alpha_{10}\ \text{Return Volatility} + \alpha_{11} \log(\text{Market Value of Equity}) \\ &+ \alpha_{12} \log(\text{Number of Trades}) \times \text{DUM}^Y + \alpha_{13} \log(\text{Number of Trades}) \times \text{DUM}^N + \varepsilon\end{aligned}$$

$$\begin{aligned}\text{Depth} = \beta_0 &+ \beta_1\ \text{DUM}^N + \beta_2 \log(\text{Share Price}) + \beta_3 \log(\text{Trade Size}) + \beta_4\ \text{Return Volatility} \\ &+ \beta_5 \log(\text{Market Value of Equity}) + \beta_6 \log(\text{Number of Trades}) \times\ \text{DUM}^Y \\ &+ \beta_7 \log(\text{Number of Trades}) \times \text{DUM}^N + \varepsilon\end{aligned}$$

where DUM^N equals one for Nasdaq stocks and zero otherwise, DUM^Y equals one for NYSE stocks and zero otherwise, $\text{QC}^{1/16}$ is the proportion of even-sixteenths among sixteenths, $\text{QC}^{1/8}$ is the proportion of even-eighths among eighths, and $\text{QC}^{1/4}$ is the proportion of even-fourths among quarters. For each stock, we calculate the average quoted spread and depth using all the time-series observations during the three-month study period. We measure share price by the mean value of the midpoints of quoted bid and ask prices, and trade size by the average dollar transaction during the study period. The number of trades is the total number of transactions during the study period. We measure return volatility by the standard deviation of daily returns calculated from the daily closing midpoints of bid and ask prices. Absolute values of *t*-statistics are reported in parentheses.

	Spread		Depth
Intercept	0.00341	Intercept	−43,645
	(3.83**)		(21.95**)
DUM^N	0.0056	DUM^N	−7,604
	(3.12**)		(2.68**)
$\text{QC}^{1/16} \times \text{DUM}^Y$	0.0185	log(Share Price)	−12,005
	(28.36**)		(40.09**)
$\text{QC}^{1/8} \times \text{DUM}^Y$	0.0014	log(Trade Size)	7,168
	(1.62)		(24.06**)
$\text{QC}^{1/4} \times \text{DUM}^Y$	0.0008	Return Volatility	144
	(1.55)		(3.14*)
$\text{QC}^{1/16} \times \text{DUM}^N$	0.0203	log(Market Value of Equity)	1,097
	(18.41**)		(6.36**)
$\text{QC}^{1/8} \times \text{DUM}^N$	0.0079	log(Number of Trades) × DUM^Y	198
	(3.34**)		(0.90)
$\text{QC}^{1/4} \times \text{DUM}^N$	0.0023	log(Number of Trades) × DUM^N	306
	(1.04)		(1.11)
1/(Share Price)	0.0865		
	(75.70**)	F-value	363.28**
log(Trade Size)	−0.0010	Adjusted R^2	0.4927
	(13.80**)		
Return Volatility	0.0000		
	(0.08)		
log(Market Value of Equity)	−0.0002		
	(4.09**)		
log(Number of Trades) × DUM^Y	0.0001		
	(1.39)		
log(Number of Trades) × DUM^N	−0.0012		
	(13.33**)		
F-value	1708.23**		
Adjusted R^2	0.8947		

** Indicates statistical significance at the 0.05 level.

* Indicates statistical significance at the 0.01 level.

spreads, and the proportions of even-sixteenths and even-eighths have a significant and positive effect on Nasdaq spreads. As expected, we find that the spread is negatively related to trade size, market capitalization, and share price, and the depth is negatively related to share price and positively related to trade size and market capitalization. These results are all consistent with those shown in Table 4 and Table 5 obtained from our matching samples of Nasdaq and NYSE stocks.

7. Summary and conclusion

Numerous studies suggest that execution costs on Nasdaq are significantly greater than those on the NYSE. Some researchers maintain that Nasdaq dealers implicitly collude to set larger spreads than their counterparts on the NYSE. Both academic research and anecdotal evidence suggest that execution costs for Nasdaq issues have declined significantly since the phased implementation of the new SEC order-handling rules. In this study, we perform a post-Nasdaq market reform comparison of Nasdaq and NYSE trading costs and depths.

Our empirical results show that the quoted, effective, and realized spreads of Nasdaq stocks are all wider than those of comparable NYSE stocks. Although the negative publicity and legal action against Nasdaq market makers and subsequent SEC rule changes have exerted a significant impact on Nasdaq quotes, Nasdaq market makers still quote wider spreads than NYSE specialists. We conjecture that wider spreads on Nasdaq could largely be attributed to the high degree of internalization and preferencing. Our empirical results also show that the average quoted depth for Nasdaq stocks is significantly smaller than the corresponding figure for NYSE stocks.

We find that liquidity providers on Nasdaq tend to quote more in even-sixteenths, even-eighths, and even-fourths than their odd counterparts. The avoidance of odd-eighth quotes reported in previous studies has largely been replaced by the avoidance of odd-sixteenths after the reduction in the minimum tick size. Our results also show that NYSE specialists quote significantly more in even-sixteenths than odd-sixteenths. We find evidence that spreads are wider for stocks that exhibit higher proportions of even-sixteenth quotes on both the NYSE and Nasdaq. In is unclear whether the positive relation between spreads and quote clustering is a result of the deliberate attempt by market makers to maintain supracompetitive spreads or an unintended outcome of investor preference toward coarse quotes. A further investigation of this issue is a fruitful area for future research.

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