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The initiation and withdrawal of odd-eighth quotes among Nasdaq stocks: an empirical analysis☆

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Abstract

Christie and Schultz (1994), (Journal of Finance, 49, 1813–1840) find that market makers in many active Nasdaq stocks avoid odd-eighth quotes. This paper studies 67 (58) Nasdaq stocks whose market makers initiate (withdraw) odd-eighth quotes. These regime shifts are often completed within the span of a day, and coincide with dramatic changes in dollar, percentage and effective spreads. In most cases, we are unable to identify comparable changes in the costs of making markets. We do identify long-run changes in average prices that may provide a partial explanation. However, we also find

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that these patterns are not shared by stocks traded in auction markets.

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1. Introduction

The degree of competition among market makers in the Nasdaq Stock Market has become a contentious issue. Much of this debate centers around alternative explanations for the findings of Christie and Schultz (1994), who offer implicit collusion as the most likely explanation for the absence of odd-eighth quotes for a majority of active Nasdaq issues in 1991. The lack of quotes ending in $\frac{1}{8}$, $\frac{3}{8}$, $\frac{5}{8}$, or $\frac{7}{8}$ implies that inside spreads are restricted to multiples of \$0.25. Thus, the minimum spread of \$0.125 cannot arise, even for the large Nasdaq issues that they study.

Interest in identifying the motive for avoiding odd-eighth quotes is not confined to academics. The public debate sparked by Christie and Schultz (1994) prompted the creation of the National Association of Securities Dealers Regulation (NASDR) arm of the NASD, and the initiation of private litigation that produced a billion dollar settlement against 33 of the largest Nasdaq market making firms. In addition, their work triggered inquiries by the Antitrust Division of the U.S. Department of Justice and the Securities and Exchange Commission (SEC).

In the summer of 1996, the Department of Justice and the SEC released their findings on the competitiveness of the Nasdaq market. Each of these agencies identified a 'pricing convention' that accounted for the absence of odd-eighth quotes. Specifically, in some Nasdaq stocks, dealers avoided odd-eighth quotes entirely and maintained individual dealer spreads of at least \$0.75. Alternatively, dealers routinely used odd-eighth quotes while restricting individual dealer spreads to less than \$0.75. Violating the pricing convention carried a stigma of 'unethical' conduct, and traders were trained to avoid making 'Chinese markets' in which odd-eighth quotes were posted in even-eighth stocks.[1]

[1] The Department of Justice, in entering into a settlement with 24 market making firms, concluded that 'the defendants and others had been engaged for a number of years in anti-competitive conduct in violation of the Sherman Act' (see, United States Department of Department of Justice, 1996, Competitive Impact Statement, p. 6). The SEC, through evidence collected from taped conversations among traders, indicated that the pricing convention was 'sometimes enforced through harassment, or threatened refusal to deal. This pricing convention directly and indirectly restricted the independent pricing decisions of individual market makers, and thereby negatively impacted price competition'. (see [SEC, 1996] 21(a) report, p. 17).

While the Government investigations have shed important light on the willingness and ability of Nasdaq market makers to engage in anti-competitive conduct, the reports are silent on a number of important issues. For example, the pricing convention per se does not address the question of why certain stocks are quoted solely in even-eighths while others are not. In other words, the Government investigations imply that market makers ignore the characteristics of the stocks they trade and simply follow a time-honored quotation tradition. Yet Christie et al. (1994) demonstrate that dealers abruptly adopted odd-eighth quotes for four of the largest Nasdaq stocks when the findings of Christie and Schultz (1994) became public in May of 1994. Thus, an important piece of the puzzle is still missing. We do not know which factor(s) induce dealers to initiate or withdraw the routine use of odd-eighth quotes, and whether these factors are consistent with the costs of market making.

Much of the previous literature has focused on the cross-sectional relation between trading costs and odd-eighth avoidance. For example, Huang and Stoll (1996) study the differences in various measures of trading costs for paired samples of NYSE and Nasdaq stocks and conclude that it is almost twice as costly to trade on Nasdaq. They attribute the differences in execution costs across markets to the structural features of Nasdaq that limit or eliminate price competition rather than to the differences in the frequency of odd-eighth quotes. In contrast, Barclay (1997), Bessembinder (1997a) and Kandel and Marx (1997) all conclude that the elimination of odd-eighth quotes inflates trading costs after controlling for factors that proxy for the costs of market making.

Unlike previous research, we examine the time-series relation between trading costs and odd-eighth frequencies, and focus on those (rare) instances when market makers shift between the use or avoidance of these price fractions. We obtain samples of 67 (58) Nasdaq stocks whose dealers start (stop) using odd-eighth quotes between January 1990 and March 1994. Our results show that market makers alter their use of odd-eighth quotes extremely rapidly, typically within one trading day. More importantly, there is an abrupt change in the magnitude of inside and effective spreads that coincides with the shift in the use of odd-eighth quotes. We identify a relatively small number of issues for which odd-eighth quotes are initiated coincident with the announcement of an impending merger or when share prices fall precipitously in the absence of a stock split. We also find transitory increases in share volume and a small but permanent increase in the number of market makers near the shift date among issues where odd-eighths are initiated. However, these effects are small relative to the dramatic decline in the costs of trading. We are unable to identify any *specific* event that triggers the *withdrawal* of odd-eighth quotes.

One interpretation of our results is that, in the absence of short-run changes in market making costs, shifts in spread-widths may be preceded by long-run changes in the fundamental variables that affect the costs of market making. The

abruptness of the shift may arise from the presence of a discrete tick size when dealers are confined to quoting within the accepted practices of the pricing convention. Consistent with this prediction, average prices increase significantly during the year prior to the withdrawal of odd-eighth quotes and decline during the year preceding the initiation of these price fractions. In addition, percentage spreads converge immediately upon the initiation and withdrawal of these price fractions. However, initiating or withdrawing odd-eighth quotes to align percentage spreads across stocks with vastly different prices is anomalous. A host of previous empirical research consistently finds that percentage spreads decrease in the price level (e.g. Demsetz, 1968; Benston and Hagerman, 1974; Stoll, 1978; McInish and Wood, 1992; Kandel and Marx, 1997).

An alternative explanation for these findings is that the shift in odd-eighths usage reflects the formation or collapse of implicit agreements among market makers to avoid odd-eighth quotes. If the convention of avoiding odd-eighth quotes is easier to maintain when stock prices are relatively high, we might expect such shifts after long-run price changes. Indirect evidence in support of this hypothesis is obtained by examining stocks that split by a factor of at least 3–2 shortly after the withdrawal of odd-eighth quotes. In each case, the post-split price is lower than the price when odd-eighth quotes are withdrawn. However, odd-eighths are not re-initiated, essentially doubling the trading costs for a given trade size after a 2–1 split. These results suggest that once stocks are quoted solely in even-eighths, this custom continues even when there are significant price changes.

The ability of market makers to maintain supra-competitive spreads is modeled by Kandel and Marx (1997). They demonstrate than an equilibrium where dealers set spreads equal to the marginal cost of trading plus two ticks is stable. Consistent with their model, we find that the initiation of odd-eighth quotes is concentrated around prices of \$10, the price at which the tick size falls from $\frac{1}{8}$ to $\frac{1}{32}$.

Finally, we examine whether NYSE or Amex stocks of similar size to our Nasdaq sample experience similar shifts in the frequency of odd-eighth quotes. Despite searching close to 5000 issues over a five-year interval, we did not identify any listed stocks that undergo a similar shift either towards or away from the avoidance of odd-eighth quotes. Thus, the initiation or withdrawal of odd-eighth quotes is a unique feature of Nasdaq during our sample period. Whatever the ultimate source of the explanation for our results, the link between trading costs and the level of spreads (both quoted and effective) displays considerably greater slack than we might otherwise have predicted.

The remainder of the paper is organized as follows. Section 2 outlines the sample selection criteria. Section 3 establishes the link between the initiation and withdrawal of odd-eighth quotes and inside spreads. Section 4 extends these results to include effective spreads by testing whether trading costs based on actual transaction prices are affected by the shift in quotation patterns. Section 5

attempts to identify contemporaneous factors that could account for the sudden change in the frequency of odd-eighth quotes. Section 6 investigates whether the initiation or withdrawal of odd-eighth quotes is preceded by long-run changes in share prices and volumes, which are both important determinants of the costs of market making. Section 6 also examines whether the Kandel and Marx (1997) model of dealer competition is consistent with our results. Section 7 studies the impact of these various effects on the long-run participation of maker makers in these stocks. Section 8 summarizes our findings and offers concluding remarks.

2. Sample identification

Our sample consists of the 250 largest Nasdaq stocks from January 1990 through March 1994, where size is defined as the market capitalization at the end of the previous calendar year. These stocks are selected using the Center for Research in Securities Prices (CRSP) Nasdaq tape. For each stock, we identify possible shifts in the frequency of odd-eighth quotes using the daily closing prices from the CRSP National Market System (NMS) tape. We calculate the average fraction of inside quotes that contain an odd-eighth in months $t-1$ and $t+1$. We retain issues if the proportion of odd-eighth quotes in month $t+1$ differs from month $t-1$ by at least 30% (e.g. 2% in month $t-1$ and 40% in month $t+1$). This criterion does not restrict the sample to issues with abrupt shifts in the frequency of odd-eighth quotes, but only requires a significant change in this frequency over the entire month t.

Once the potential sample of stocks are identified, intraday quote data are obtained from the Institute for the Study of Securities Markets (ISSM) prior to January 1993, and from the NYSE Trade and Quote (TAQ) database from January 1993 onward. The intraday data are collected for the two calendar months before month t through the two calendar months after month t. The date of the shift in the frequency of odd-eighth quotes is identified using the intraday data. The daily fraction of odd-eighth quotes is assumed to follow a binomial distribution. The probability that k of the N quotes on day t lie on an odd-eighth is given by

$$\binom{N_t}{k_t}\rho^{k_t}(1-\rho)^{N_t-k_t}, \tag{1}$$

where ρ is the probability of an odd-eighth quote. This probability is allowed to change once during the sample period.

To identify the date when the use of odd-eighth quotes changes, we maximize the following likelihood function with respect to the shift date t_s, the probability of an odd-eighth quote before the shift ρ_b, and the probability of an odd-eighth

Table 1
Distribution of the average number of market makers, share price, market value of equity, average share volume and dollar spread during the month preceding the initiation or withdrawal of odd-eighth quotes.The sample includes 67 issues whose market makers initiate odd-eighth quotes (Panel A) and 58 issues whose market makers withdraw odd-eighth quotes (Panel B) between 1990 and 1994. Market makers, prices and outstanding shares are obtained from the CRSP Nasdaq tape, while dollar spreads are computed using the ISSM and TAQ databases. Dollar spread calculations are based on all quote revisions that reflect a change in either the inside bid or ask between 9:30 a.m. and 4:00 p.m.

	Market makers	Price per share	Market value (000's)	Share volume	Dollar Spread (in cents)
Panel A: Results for the month prior to the initiation of odd-eighth quotes					
20% Percentile	13.0	\$8.24	\$63,884	54,145	36.91
40% Percentile	17.1	10.10	143,844	117,104	39.77
60% Percentile	25.0	13.82	274,002	197,048	42.32
80% Percentile	32.6	21.20	478,796	357,047	49.23
Median	19.1	12.52	199,197	168,750	41.40
Mean	23.3	14.67	483,502	340,998	44.64
Panel B: Results for the month prior to the withdrawal of odd-eighth quotes					
20% Percentile	12.0	\$13.97	\$97,735	50,307	26.77
40% Percentile	15.7	17.41	145,720	90,686	30.40
60% Percentile	19.0	23.45	282,509	151,008	32.99
80% Percentile	22.0	30.50	528,119	291,269	35.60
Median	17.2	20.06	211,361	115,027	31.85
Mean	17.9	23.35	528,119	200,702	31.67

quote after the shift ρ_a:

$$\prod_{t=1}^{t=t_{s-1}} \left[\binom{N_t}{k_t} \rho_b^{k_t} (1-\rho_b)^{N_t-k_t} \right] x \prod_{t=t_s}^{t=T} \left[\binom{N_t}{k_t} \rho_a^{k_t} (1-\rho_a)^{N_t-k_t} \right]. \tag{2}$$

N_t is defined as the number of quotes on day t, and k_t represents the number of odd-eighth quotes on day t. If a chi-square test indicates that the difference between the likelihood function calculated with one probability and the likelihood function calculated with two probabilities is not significant at the 5% level, we exclude the observation. We also exclude inactive stocks where a single quote revision reflects a change in the use of odd-eighths, but where the quote is not revised for several days. This additional criterion eliminates approximately 14% of the remaining sample.

The final sample includes 67 (58) issues whose market makers initiate (withdraw) odd-eighth quotes. Table 1 provides the distribution of the number of

market makers (compiled from the CRSP/NMS tapes), share price, market value, share volume, and dollar spread during the month preceding the initiation (Panel A) or the withdrawal (Panel B) of odd-eighth quotes. The table shows that, on average, issues whose dealers initiate odd-eighth quotes have more market makers, lower share prices, lower market values, and higher share volume during the month preceding the shift than do issues where odd-eighth quotes are withdrawn. The largest difference between the initiation and withdrawal samples lies in the distribution of share prices. The average share price among issues in which odd-eighths are withdrawn is typically 60% higher at each quartile. The last column provides the distribution of average dollar spreads. The median spread of \$0.41 for issues not routinely quoted in odd-eighths is almost 30% wider than the average of \$0.32 for issues in which odd-eighth quotes are common.

A comparison of the two samples reveals that 7 issues appear in both. For each of these issues, odd-eighth quotes are withdrawn between September 1990 and February 1992 and re-initiated between October 1992 and October 1993. The average time interval during which odd-eighth quotes are absent from these issues is slightly over two years, highlighting the stability of the pricing convention over time. This inference is reinforced by the observation that odd-eighth quotes are not reinstated prior to March 1994 for any of the remaining 51 in the withdrawal sample despite the vast majority of these firms entering this sample in 1990 and 1991.

3. The relation between odd-eighth quotes and inside spreads

In this section, we first examine the time-series relation between the frequency of odd-eighth quotes and the width of inside spreads. We further investigate this relation by studying the frequency distribution of spread widths as a function of the use or avoidance of odd-eighth quotes. Finally, we examine whether the observed shifts in the use of odd-eighth quotes also exist among stocks traded on the NYSE or Amex.

3.1. Time-series results

Fig. 1 plots the average inside spread and the average fraction of odd-eighth quotes for the 67 issues whose dealers initiate odd-eighth quotes. These series are plotted using a 120-day window centered on the shift date, designated as day 0. Although there is a slight increase in the fraction of odd-eighths between days -5 and -1, the fraction jumps from approximately 5% on day -1 to 35% on day 0, increasing to approximately 45% by day 1. The sudden adoption of odd-eighth quotes has an equally dramatic impact on the width of the average

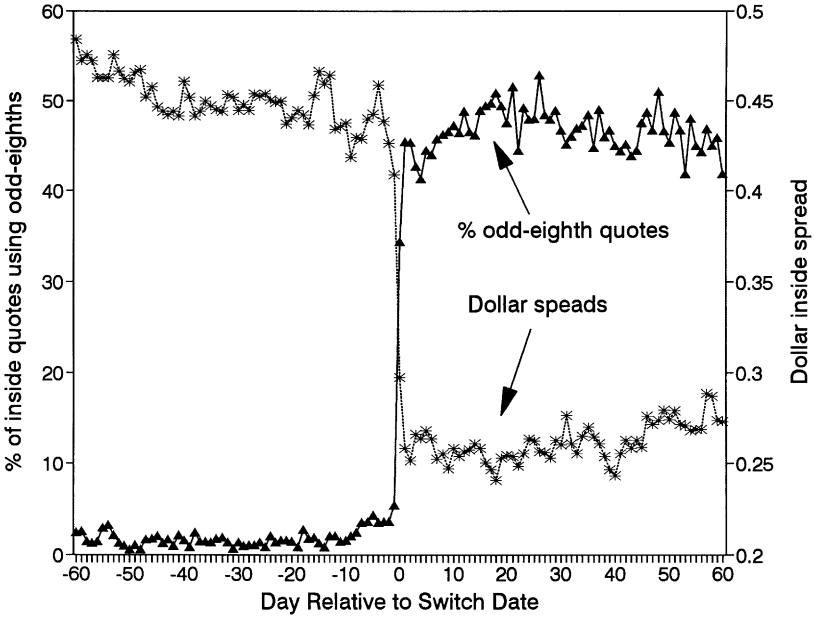


Fig. 1. The average percentage of inside spreads that contain an odd-eighth quote and the average inside dollar spreads for the 67 issues whose market makers started using odd-eighth quotes routinely between 1990 and 1994. The average fraction of inside quotes that contain an odd-eighth and the average dollar inside spread are calculated using all quote revisions that reflect a change in either the inside bid or ask between 9:30 a.m. and 4:00 p.m. Day 0 is defined as the date that odd-eighth quotes were initiated.

inside spread, which declines from approximately 42 cents per share on day -1 to 25 cents per share within two trading days.[2]

Fig. 2 plots the average inside spread and the average fraction of odd-eighth quotes for the sample of 58 issues whose market makers stop using odd-eighth quotes. The average fraction of odd-eighth quotes varies between 43% and 53% during days $[-60, -12]$. This range decays slightly to between 40% and 45% in the interval $[-11, -5]$, and falls to almost 30% by day -1. The average fraction of odd-eighth quotes then declines to approximately 8% on day 0, and remains under 3% after day 8. Fig. 2 also shows that inside spreads and the

[2] Christie et al., 1994 (CHS, 1994) find that virtually all dealers move in unison to adopt odd-eighth quotes for four of the five stocks that they study around May 27, 1994. The similarities between Fig. 1 and the results in CHS suggest that the dramatic rise in odd-eighth quotes and the associated narrowing of spreads for our sample is also associated with the rapid adoption of these price fractions by all market makers.

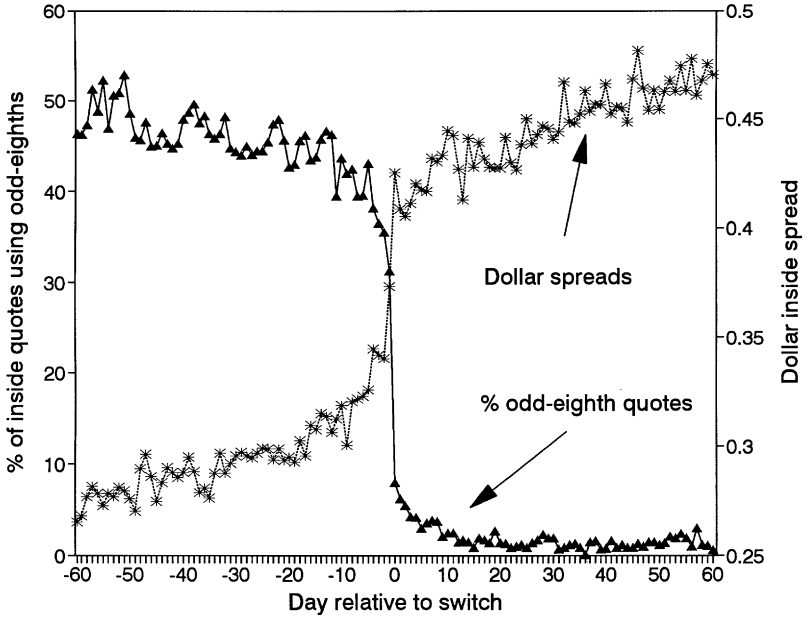


Fig. 2. The average percentage of inside spreads that contain an odd-eighth quote and the average inside dollar spread for the 58 issues whose market makers stopped using odd-eighth quotes routinely between 1990 and 1994. The average fraction of inside quotes that contain an odd-eighth and the average inside dollar spread are calculated using all quote revisions that reflect a change in either the inside bid or ask between 9:30 a.m. and 4:00 p.m. Day 0 is defined as the date that odd-eighth quotes were withdrawn.

fraction of odd-eighth quotes are inversely related. The inside spread varies between \$0.25 and \$0.32 through day -10, and fluctuates between \$0.41 and \$0.48 during the period [10, 60]. These results demonstrate that market makers, who are presumed to compete independently for orders through competitive quotes, can move swiftly and in unison to stop using all available price fractions.[3]

One result that is common across the initiation and withdrawal samples is the intraday speed of adjustment in quotation patterns on days -1 and 0. The

[3] To assess whether the decreased use of odd-eighth quotes immediately prior to day 0 is shared by all issues, we test for differences in the average fraction of odd-eighth quotes during the intervals $[-60, -5]$ and $[-5, -1]$. This difference is significant at the 5% level for only 22 of the 58 issues. In addition, there are an average of 3.9 more dealers among the issues where odd-eighths are removed more slowly. This difference (significant at the 5% level), implies that a coordinated shift to even-eighth quotes is marginally more difficult with a larger number of dealers.

fraction of odd-eighth quotes displays a permanent shift during the afternoon on day −1 for both samples. The largest shift in the use of odd-eighth quotes occurs immediately after the market opens on day 0. The fraction of odd-eighth quotes increases to over 30% for stocks in the initiation sample, while the fraction declines below 10% by 10:00 a.m. among stocks in the withdrawal sample on day 0. Thus, most of the shift occurs within the span of a few hours.

One feature of the Nasdaq market that might contribute to the coordinated adoption or elimination of odd-eighth quotes is the presence of the Excess Spread Rule (ESR). During our sample period, this rule stipulated that the spreads of individual dealers must be no wider than 125% of the average width of the three dealers posting the narrowest spreads. While the intention of the ESR was to prevent dealers from making markets in name only, the effect of the rule was to induce a degree of interdependence in quotes. Specifically, if three dealers followed the pricing convention and narrowed their individual dealer spreads to under \$0.75 while adopting odd-eighth quotes, all other dealers would have been obligated to follow suit. Thus, the rapid increase in odd-eighth use could have been an artifact of the ESR. However, the swift withdrawal of these quote fractions would appear to require a higher degree of coordination among market makers in the presence of the ESR.

3.2. The relation between spread-widths and odd-eighth frequencies

The results in Section 3.1 demonstrate the link between the frequency of odd-eighth quotes and the width of inside spreads. This section pursues this link by studying the frequency distribution of spread widths as a function of the use or avoidance of odd-eighth quotes. For example, does the use of odd-eighth quotes necessarily drive spreads to their regulatory minimum of \$0.125? Similarly, are the narrower spread-widths less frequent among stocks whose market makers use odd-eighth quotes immediately prior to the withdrawal of odd-eighth quotes relative to the frequency after market makers initiate these price fractions? In other words, is there a relation between the distribution of spread-widths and the initiation and withdrawal of odd-eighth quotes?

Table 2 presents the distribution of inside spread-widths for both the initiation and the withdrawal samples during the intervals $[-60, -1]$ and $[0, 60]$. For each stock, we compute the average fraction of all inside spreads of specific widths. We then compute the percentiles of that distribution for each spread-width. Panel A presents the results for the initiation sample, and Panel B presents the findings for the withdrawal sample.

The periods of odd-eighth avoidance either precede the initiation of odd-eighth quotes or follow their withdrawal. Table 2 shows that when odd-eighth quotes are routinely avoided, the distribution of spread-widths is quite similar between the two samples. For example, the median fraction of \$0.50 spreads is

Table 2
Summary of the distribution of the fraction of spread widths surrounding the introduction or withdrawal of odd-eighth quotes. The sample includes 67 (58) issues whose market makers initiate (withdraw) odd-eighth quotes between 1990 and 1994. For each stock, we calculate the fraction of inside quote revisions that produce spreads of \$0.125, \$0.25, \$0.375, \$0.50, or larger than \$0.50 during the period [− 60, − 1] and [0, 60]. We then report the percentiles for each of these spread widths across stocks

Panel A: Results for the 67 issues whose market makers initiate odd-eighth quotes

Percentile	Spread prior to the adoption of odd-eighths					Spread after the initiation of odd-eighths				
	\$0.125	\$0.25	\$0.375	\$0.50	> \$0.50	\$0.125	\$0.25	\$0.375	\$0.50	> \$0.50
20th	0.0%	23.3%	1.0%	45.0%	0.9%	14.3%	39.9%	7.5%	0.4%	0.0%
40th	0.4	35.0	1.7	47.0	5.3	24.8	47.1	16.9	1.3	0.0
50th	0.6	39.9	1.9	48.0	6.6	27.5	48.0	20.4	2.1	0.0
60th	0.7	42.7	2.2	49.1	12.0	31.5	49.2	23.3	3.8	0.0
80th	1.2	49.2	3.6	50.9	23.6	44.2	49.9	28.5	12.0	1.4

Panel B: Results for the 58 issues whose market makers withdraw odd-eighth quotes

Percentile	Spread prior to the withdrawal of odd-eighths					Spread after the withdrawal of odd-eighths				
Percentile	\$0.125	\$0.25	\$0.375	\$0.50	> \$0.50	\$0.125	\$0.25	\$0.375	\$0.50	> \$0.50
20th	9.0%	34.7%	22.9%	3.0%	0.0%	0.1%	24.4%	1.2%	46.1%	3.6%
40th	11.3	40.6	30.5	5.7	0.1	0.4	34.1	2.1	47.5	5.7
50th	13.4	41.9	31.5	9.1	0.2	0.5	37.2	2.6	48.0	11.0
60th	17.0	43.8	34.4	11.6	0.4	0.8	40.5	3.1	48.8	12.7
80th	27.4	47.9	39.3	16.7	1.5	1.3	44.6	4.5	50.2	23.1

48% both prior to the initiation of odd-eighths and after their withdrawal. Similarly, the median fraction of \$0.25 spreads is 39.9% before odd-eighth quotes are initiated and 37.2% after odd-eighths are withdrawn.

There is, however, a considerable difference in the distribution of spread-widths across samples during the intervals in which odd-eighths are quoted. Panel A shows that after odd-eighth quotes are initiated, the median frequency of \$0.125 spreads is 27.5%, and the median frequency of spreads of at least \$0.50 is only 2.1%. In contrast, Panel B indicates that the frequency of narrower spread-widths is considerably lower among stocks whose market makers are about to withdraw odd-eighth quotes. Specifically, the median frequency of \$0.125 inside spreads prior to the withdrawal of odd-eighth quotes is only 13.4%. This is less than half the percentage associated with this spread-width following initiation of odd-eighth quotes. In fact, the median frequency of \$0.125 spreads after odd-eighth quotes are initiated (27.5%) is not reached until the 80th percentile for the withdrawal sample prior to the regime shift. The table also shows that prior to the withdrawal of odd-eighth quotes, spread-widths of \$0.50 are not uncommon, with a median frequency of 9.1%. This result may partly reflect the decreased use of odd-eighth quotes during the period immediately prior to the withdrawal date.

These results have two important implications for the link between the use of odd-eighth quotes and the width of inside spreads. First, the presence of relatively wide spreads among stocks whose market makers use odd-eighth quotes is not consistent with the hypotheses that that the avoidance of odd-eighth quotes is necessitated by the need for wide spreads (see Kleidon and Willig, 1995; Grossman et al., 1997). Second, and perhaps more important, is that the frequency of inside spreads of \$0.125 is much higher after the initiation of these price fractions than prior to their withdrawal. Indeed, the entire distribution of spread frequencies is tilted towards the narrower spreads after the initiation of odd-eighth quotes in Panel A relative to the period preceding the withdrawal of these quotes in Panel B. Thus, although the use of odd-eighth quotes does not result in a high concentration of one-eighth spreads, the narrower spread widths are more likely to arise after market makers initiate the use of these quotes. However, it is also important to emphasize that the differences in spread-width frequencies prior to the withdrawal or after the initiation of odd-eighth quotes is minor relative to the differences across regimes that do or do not use these quote fractions.

3.3. Do NYSE/Amex issues also experience sudden shifts in odd-eighths use?

This section discusses whether the phenomenon that we study in this paper is limited to Nasdaq stocks. If the pattern of abrupt shifts in the use of odd-eighth quotes is common across market structures, then issues of anti-competitive behavior on the part of Nasdaq market makers become less relevant. In

addition, the study of other markets can shed light on the forces that prompt the swift change in the frequency of odd-eighth quotations.

We first select a sample of issues drawn from the NYSE and Amex between 1990 and 1994 whose market capitalization meets the criterion used to select the Nasdaq sample. The number of issues that satisfy this criterion range from a low of 947 issues in 1992 to 1017 in 1994. We then use the CRSP daily master file to assess whether the frequency of odd-eighth prices computed from the daily closing prices changed by at least 30% between month $t-1$ and $t+1$ during the period January 1990 through March 1994. This additional criterion reduces the sample to 58 potential shifts among 38 different issues. We further refine our search by testing for the 30% difference in the frequency of odd-eighths using all the intraday quotes from ISSM and TAQ. This additional criterion eliminates all but one stock, Westco Financial, whose market makers increase the frequency of odd-eighths quotes from 29.8% in November 1992 to 60.7% in December of 1992. Since neither of these months meet our definition of odd-eighth avoidance (i.e., fewer than 10% odd-eighth quotes), we conclude that the initiation and withdrawal of odd-eighth quotes is an artifact of the dealer market that is not replicated among similar sized stocks on either the NYSE or Amex. This result may not be surprising since the auction market is heavily influenced by the liquidity supplied by public limit orders, while the dealer market on Nasdaq is dominated exclusively by the market maker community without the benefit of price competition from other sources during the period of our study.

4. The relation between odd-eighth quotes and effective spreads

While Section 3 illustrates the association between quoted inside spreads and the frequency of odd-eighth quotes, this section measures trading costs by computing effective spreads, since investors differ in their ability to by-pass dealer quotes. Orders that are entered into the Small Order Execution System (SOES) are eligible for automatic execution against the posted quotes, implying that inside spreads represent prices for smaller orders. In contrast, larger orders may receive price improvement through the negotiation process. Thus, we calculate effective spreads, which take into consideration the location of the trade relative to the posted quotes. The effective spread for trade t in firm i is defined as

$$ES_{i,t} = \left| Price_{i,t} - \left(\frac{Ask_{i,t} + Bid_{i,t}}{2} \right) \right|, \tag{3}$$

where $Price_{i,t}$ is the trade price, and $Ask_{i,t}$ and $Bid_{i,t}$ are the inside bid and ask prices when the trade is executed. If trades are routinely executed within the spread, the initiation or withdrawal of odd-eighth quotes may not adversely

Table 3
Effective spreads for the initiation and withdrawal samples. Effective spreads for each trade are computed using the inside bid and ask price in effect at the time the trade is reported, and are calculated as

$$Eff\ Spd_{i,t} = \left| Price_{i,t} - \frac{Inside\ Ask_{i,t} + Inside\ Bid_{i,t}}{2} \right|.$$

The initiation and withdrawal samples consist of 67 and 58 stocks whose market makers initiated or withdrew, respectively, odd-eighth quotes between 1990 and 1994. We exclude trades without valid quotes, trades in which the inside quotes are locked or crossed, and trades in which the actual trade price is outside the best bid or offer. Average effective spreads are computed after combining all trades for each sample. Day 0 designates the date that odd-eighth quotes are initiated/withdrawn. Effective spreads are reported as cents/share. All pair-wise comparisons between periods $[-60, -1]$ and $[0, 60]$ are statistically significant at the 1% level

Trade size (Shares)	Initiation sample		Withdrawal sample	
	-60 to -1	0 to 60	-60 to -1	0 to 60
100	32.1	19.0[a]	27.2	41.5[a]
200	31.0	18.7[a]	26.6	39.8[a]
300	30.0	18.5[a]	25.9	37.9[a]
400	29.1	18.1[a]	24.9	36.1[a]
500	27.1	17.3[a]	23.3	33.7[a]
600–1000	23.2	14.9[a]	17.7	26.0[a]
1100–5000	18.6	13.6[a]	18.3	25.4[a]
5100–10,000	21.6	14.2[a]	19.0	26.5[a]
$>10{,}000$	20.9	14.2[a]	18.1	25.4[a]

[a]Designate values estimated between [0, 60] that differ from the values estimated between $[-60, -1]$ at the 1% level of statistical significance.

impact effective spreads among the larger trade sizes where investors can negotiate to finer price increments.[4]

Table 3 presents the average effective spreads for the initiation and the withdrawal samples. The estimates are computed by pooling trades across stocks during the period prior to the regime shift $[-60, -1]$ or after the regime shift [0, 60]. Table 3 shows that the dramatic change in inside spreads due to the initiation or withdrawal of odd-eighth quotes is shared by effective spreads. Specifically, after odd-eighths are withdrawn, effective spreads increase

[4] Bessembinder (1997a) decomposes effective spreads into the fractions attributable to price impact and to realized profit. He finds evidence consistent with the hypothesis that Nasdaq market makers extract supra-competitive revenues when stocks are quoted solely on even-eighths. Thus, he concludes that the degree of price-rounding on Nasdaq translates into higher trading costs for investors relative to similar NYSE issues.

by approximately 50% for trades of 500 shares or less, and by close to 40% for block trades in excess of 10,000 shares. In dollar terms, effective spreads for 100-share trades increase from 27.2 cents per share during the period $[-60, -1]$ to 41 cents per share after odd-eighth quotes are withdrawn. Similarly, effective spreads rise from 18.1 to 25.4 cents per share for block trades in excess of 10,000 shares. Clearly, the withdrawal of odd-eighth quotes produces an increase in effective spreads that parallels the dramatic widening of inside spreads noted in Fig. 2.[5]

Table 3 also shows that the initiation of odd-eighth quotes triggers significant reductions in effective spreads. These reductions range from 40% for trades of 100 shares to 33% for block trades over 10,000 shares. Thus, trading costs decline when odd-eighths quotes are regularly used, independent of the chosen trade size. Similarly, the withdrawal of these price fractions is detrimental to investors regardless of their trade size.

5. Do contemporaneous events explain the change in quotation patterns?

In light of the swift speed of transition between the routine use and avoidance of odd-eighth quotes, this section studies whether the results can be explained by sudden shifts in factors that are thought to affect trading costs.

5.1. Announcement effects

We examined the *Wall Street Journal Index* surrounding the shift date to identify specific news events that might account for the change in the use of odd-eighth quotes. We are unable to identify any incident in the period surrounding the shift dates to explain the withdrawal of odd-eighth quotes. However, the search for possible explanations for the initiation of odd-eighth quotes met with greater success. Table 4 summarizes the events that either coincide with or lie in close proximity to the adoption of odd-eighth quotes. These explanations fall into two categories: (1) the announcement of a merger, and (2) a dramatic decline in share prices. Table 4 shows that 15 of the 67 issues whose market makers initiate odd-eighth quotes announce that they are to be acquired. In 13 of the 15 cases, the shift in odd-eighths use occurs within one trading day of the merger announcement.

The motive behind the change in quotation patterns coincident with the merger is unclear. One hypothesis is that the pricing convention is a mechanism to maintain supra-competitive spreads that emerges from an infinite game

[5] The transition to higher effective spreads coincides with the date that odd-eighth quotes are withdrawn. Graphical evidence is available from the authors on request.

Table 4
Summary of news events immediately surrounding the initiation of odd-eighth quotes for 19 stocks. The switch date is defined as the day that odd-eighth quotes start to be used on a regular basis. The Wall Street Journal (WSJ) story represents a major news event that is reported in close proximity to the date that odd-eighth quotes are initiated. The total sample consists of 67 stocks whose market makers initiated the use of odd-eighth quotes between 1990 and 1994

Stock	Switch date	WSJ story	Explanation
The Office Club	12/21/90	12/21/90	Acquired by Office Depot
Dow B. Hickman	6/28/91	6/28/91	Acquired by Mylan Labs
Sanford Corp	11/27/91	11/25/91	Acquired by Newell Co.
Teradata Corp	12/02/91	12/03/91	Acquired by AT&T
XL/Datacomp Inc.	8/05/91	8/06/91	Acquired by Storage Tech
Applied Biosystems Inc.	10/07/92	10/07/92	Acquired by Perkin-Elmer
Goal Systems Intl.	4/03/92	4/03/92	Acquired by Legent Corp.
Intelligent Electronics	7/08/92	7/07/92	Unit sale through stock sale
Puget Sound Bancorp	3/10/92	3/10/92	Acquired by KeyCorp
Engraph Inc.	9/14/93	9/14/93	Acquired by Sonoco
First United Bank Group	7/29/93	7/28/93	Acquired by Norwest
Medco Container Services	7/28/93	7/29/93	Acquired by Merck & Co.
Med. Marketing Corp.	11/17/93	11/17/93	Acquired by Medco
Rehabclinics Inc.	10/25/93	10/22/93	Acquired by NovoCare
Aldus Corp.	3/21/94	3/16/94	Acquired by Adobe
Life Core Biomedical	10/05/92	10/06/92	Price fell by 77%
Synergen Inc.	2/24/93	2/23/93	Price fell by 68%
Quarterdeck Office Systems	7/02/92	7/02/92	Price fell by 55%
Health Care COMPARE Corp.	4/05/93	4/01/93	Price fell by 30%

(Christie and Schultz, 1994). Is so, then the announcement of an impeding delisting signals the conclusion of that game, and market makers begin competing more aggressively using prices. However, this explanation is not consistent with the findings of Christie and Huang (1994) and Barclay (1997) in their studies of stocks that move their trading location from Nasdaq to either the NYSE or Amex. For these issues, the narrowing of inside spreads coincides with the date of listing on an exchange, rather than with the public disclosure that the issues would be relocating to an auction market.

Finally, the table also highlights four cases where stock prices fall precipitously (in one case by 77%) coincident with the adoption of odd-eighth quotes. In each case, the Wall Street Journal Index indicates that the stock price decline is associated with the release of new information. Life Core Biomedical 'disclosed that trial tests of a surgical anti-adhesive agent weren't demonstrating expected results'. In the case of Synergen Inc., its price fell 'after results for a major trial of its flagship drug indicated another setback in the search for a widely affective drug for sepsis, a potentially lethal blood infection'. Quarterdeck Office Systems suffered a price decline 'after the company projected sharply

lower earnings for the quarter ended June 30, 1992'. Finally, the price of Health Care COMPARE declined 'as analysts rescinded their buy recommendations'.

5.2. Stock splits and the incidence of odd-eighth quotes

The relation between price levels and the initiation of odd-eighth quotes suggested by the findings in Table 4 can be examined from a different perspective by studying the relation between stock splits and the frequency of odd-eighth quotes. Christie and Schultz (1994) find that stock splits of at least 3–2 have no impact on the frequency of odd-eighths quotes for stocks whose dealers quote exclusively in even-eighths. Thus, large price changes do not necessarily result in the adoption of odd-eighth quotes. We perform a similar experiment by identifying all stock splits of at least 3–2 in the period around the initiation or withdrawal of odd-eighth quotes. We then compare the timing of the stock split with the shift date.

The results are presented in Table 5. The table provides (1) the shift date and the corresponding share price, and (2) the effective date of the split, the split factor, and the pre-split and post-split prices. Panel A presents the results for the three issues in the initiation sample. The split date and the shift date coincide for Charter One Financial. Market makers for Astec Industries initiate odd-eighth quotes approximately two weeks prior to the split. Finally, the share price for Old Kent Financial Corp. falls from \$41.90 to \$27.15 after a 3–2 split. However, odd-eighth quotes are not used for almost two months, and then at a share price of \$29.13. Thus, the decrease in price that would have likely prompted market makers to initiate odd-eighths occurs two months prior to the shift date.

Panel B presents the results for our sample of issues where odd-eighths quotes are discontinued. If odd-eighth quotes are withdrawn only after prices have risen beyond a specific threshold, this threshold may differ across issues but it would remain relatively constant for the same issue over a short time interval. For each issue in Panel B, market makers withdraw odd-eighth quotes prior to the effective date of the split. Thus, if higher share prices are responsible for the absence of odd-eighth quotes, we might expect these quotes to reappear if the post-split price falls below the price at which odd-eighths are withdrawn. In five of the six cases reported in Panel B, the post-split price falls below the price at which odd-eighth quotes vanish, yet odd-eighth quotes are not reinstated.

Specifically, consider the cases of Electronic Arts and Novellus Systems, each of which split 2–1. Dealers stop using odd-eighth quotes for Electronic Arts at an average price of \$44.58. Two months later, the average post-split price is \$23.48, yet the issue remains quoted exclusively in even-eighths. Even more striking, odd-eighth quotes are discontinued for Novellus Systems at an average price of \$33.21. The average post-split price after two months is \$10.41. Yet, market makers fail to adopt odd-eighth quotes, despite a decline in price of almost two-thirds relative to the shift date.

Table 5
The change in the usage of odd-eighth quotes in relation to the timing of stock splits. The table compares the share prices at the initiation or withdrawal of odd-eighth quotes to the prices subsequent to stock splits that occur in close proximity to the altered use of odd-eighth quotes. For the sample of stocks whose market makers withdraw odd-eighth quotes, these price fractions are not reinstated following the split.

Panel A: Issues whose market makers initiated odd-eighth quotes

Stock	Switch to mixed-eighths		Stock split			
	Date	Share price	Date	Split factor	Pre-split price	Post-split price
Astec Industries	9/03/93	$24.06	9/13/93	2–1	$24.75	$12.77
Charter One Financial	11/22/93	29.16	11/22/93	3–2	29.16	19.48
Old Kent Financial	11/11/92	29.13	9/16/92	3–2	41.90	27.15

Panel B: Issues whose market makers withdrew odd-eighth quotes

Stock	Switch to even-eighths		Stock split			
	Date	Share price	Date	Split factor	Pre-split price	Post-split price
AST Research Inc.	1/02/91	$36.99	2/26/91	2–1	$54.04	$27.60
The Score Board Inc.	9/06/91	14.10	11/26/91	3–2	33.88	24.25
Electronic Arts	1/17/92	44.58	3/27/92	2–1	49.84	23.48
50-Off Stores	8/16/91	26.66	10/07/91	3–2	34.30	23.25
Novellus Systems	6/27/90	33.21	8/22/90	2–1	18.72	10.41
US Healthcare Inc.	3/28/91	53.59	5/13/91	3–2	44.93	30.31

These results imply that once a pattern of quoting stocks exclusively in even-eighths is adopted, the practice continues in spite of a dramatic change in one of the underlying determinants of spreads. These findings do not support the presumed link between changes in stock prices and the avoidance of odd-eighth quotes. However, the results may also reflect the presence of a fixed cost or friction in the transition between the use or avoidance of odd-eighth quotes. One such cost is imposed by the Excess Spread Rule, which may retard the ability of dealers to coordinate their quotation patterns to return to the sole use of even-eighth quotes within the terms of the pricing convention.

5.3. Event study results

This section examines whether there are significant changes in the number of dealers, turnover (the fraction of outstanding shares traded in a given day), or market-adjusted returns on the shift date. Market-adjusted returns are

computed as the portfolio return minus the return on the equally-weighted Nasdaq index. Abnormal turnover and changes in the number of dealers are tested against their averages estimated during the comparison period, defined as $[-200, -15]$. The *t*-statistics for the market-adjusted returns test for differences from zero. The initiation sample excludes issues where the shift date coincides with a merger announcement.

The results are reported in Table 6. First, consider the sample of issues where odd-eighth quotes are withdrawn. The table shows a slight decline in the number of market makers on the shift date that is statistically significant at the 5% level. The average market-adjusted return on the shift date is 1%, which is not significant at conventional levels. The most striking result is the increase in turnover. The average turnover, which is 1.25% in the comparison period, climbs to 1.95% on day -1 and reaches a maximum of 2.44% on day 0. Thus, the day that market makers cease using odd-eighth quotes is characterized by a twofold increase in turnover and a small decrease in the average number of market makers.

The results for the sample of issues whose market makers initiate odd-eighth quotes show that the average number of market makers increases by approximately 5%, or one market maker, precisely on day 0. However, it would be surprising if an increase in the average number of market makers from 20 to 21 could produce a decline in spreads of approximately 40%. One benchmark against which to compare this result is Wahal (1995), who states that 'large scale entry is associated with significant declines in daily quoted bid–ask spreads'. Specifically, he finds that the largest declines in spreads occur among stocks with a small number of market makers. In contrast, the average dollar spread is virtually unchanged when the entry of market makers is confined to stocks that are initially traded by more than 15 market makers. Since the average number of market makers for our stocks exceeds 20, it is unlikely that the decline in spreads can be attributed to the change in the number of dealers.[6]

Table 6 also shows that, for the initiation sample, turnover rises from an average of 1.19% during the non-event period to 2.06% on day -3, attains a maximum of 3.97% on day -2, and remains above 2% through day 2. Thus, the initiation of odd-eighth quotes is preceded by a dramatic increase in volume up to three days prior to the shift in quotation patterns. Finally, the average market adjusted returns are significantly negative on days -3 through -1, but not significantly different from zero on day 0.

[6] While the addition of one market maker is unlikely to alter the behavior of the other dealers, it is possible that the identity of the marginal dealer is important. Specifically, if a prominent dealer begins quoting the stock and changes the frequency of odd-eighth quotes in adherence with the pricing convention, other dealers may begin to mimic the new entrant. Unfortunately, our data do not permit us to identify the identity of the individual dealers.

Table 6
Changes in the number of market makers, abnormal turnover, and returns surrounding the change in the pattern of odd-eighth quotes. The change in the number of market makers is the difference between the change in the actual number of dealers per day and the average daily change computed over the interval [− 200, − 12]. Turnover is defined as the share volume as a percentage of the number of shares outstanding. Abnormal turnover is computed as the difference between the actual turnover and the comparison period average. Market adjusted returns are the portfolio returns minus the equal-weighted NASDAQ index. *T*-statistics (shown in parentheses) for the market returns test for differences from zero, while the *t*-statistics for the remaining variables test for differences from their control period average. The initiation sample excludes issues in which the adoption of odd-eighth quotes coincides with a merger announcement, as reported in Table 4. The final initiation sample includes 52 issues and the withdrawal sample includes 58 issues, over the 1990–1994 period

Day relative to shift	Initiation sample			Withdrawal sample		
	Change in market makers	Abnormal turnover	Market adjusted returns	Change in market makers	Abnormal turnover	Market adjusted returns
− 5	− 0.03%	− 0.28%	− 0.78%	− 0.27%	0.23%	0.88%
	(− 0.65)	(− 1.26)	(− 1.29)	(− 0.66)	(1.08)	(1.60)
− 4	− 0.33	− 0.22	0.04	− 0.11	0.17	0.24
	(− 0.71)	(− 0.99)	(0.07)	(− 0.26)	(0.83)	(0.44)
− 3	− 0.51	0.87	− 2.86	0.38	0.14	0.12
	(− 1.10)	(4.01)	(− 4.75)	(0.93)	(0.67)	(0.22)
− 2	1.19	2.78	− 3.09	− 0.16	0.47	− 0.09
	(2.57)	(12.78)	(− 5.14)	(− 0.39)	(2.25)	(− 0.17)
− 1	− 0.28	1.93	− 3.10	− 0.08	0.70	0.42
	(− 0.61)	(8.85)	(− 5.15)	(− 0.20)	(3.34)	(0.76)
0	4.94	2.41	− 1.05	− 0.80	1.19	1.00
	(10.66)	(11.07)	(− 1.74)	(− 1.98)	(5.69)	(1.81)
1	0.07	1.01	0.57	− 0.45	0.73	− 0.19
	(1.51)	(4.63)	(0.94)	(− 1.11)	(3.49)	(− 0.34)
2	− 0.04	0.79	− 0.02	− 0.08	0.61	− 0.61
	(− 0.10)	(3.62)	(− 1.03)	(− 0.19)	(2.91)	(− 1.10)
3	0.37	0.14	0.48	1.21	0.54	1.06
	(0.79)	(0.65)	(0.80)	(3.01)	(2.59)	(1.93)
4	− 0.09	0.28	0.46	− 0.48	0.40	0.33
	(− 0.19)	(1.27)	(0.76)	(− 1.19)	(1.90)	(0.60)
5	0.18	0.38	0.05	− 0.01	0.64	− 1.35
	(0.38)	(1.76)	(0.08)	(− 0.02)	(3.07)	(− 2.44)

The dramatic increase in turnover immediately prior to the initiation of odd-eighth quotes is consistent with Dutta and Madhavan (1997) who predict that 'under tacit collusion, the bid–ask spread will narrow in abnormally high volume periods'. However, the increase in turnover for the initiation sample

does not extend beyond day 2, reducing the apparent importance of this variable. In addition, we would not expect the same increase in volume to result in the withdrawal of odd-eighth quotes. Yet, this is exactly what we observe in Table 6. Thus, the evidence provides few clues to help explain why Nasdaq market makers initiate or withdraw odd-eighth quotes for these issues.[7]

In summary, our search for a significant change in the costs of making markets coincident with the regime shift in odd-eighth quotes has been relatively unsuccessful, particularly among the issues in which odd-eighth quotes are withdrawn. However, the results may also reflect our failure to correctly identify all the relevant forces that drive trading costs, or the need to search for longer-run changes in the costs of market making. We address the latter possibility in the following section.

6. Long-run changes in market making costs

In our search for changes in the long-run costs of market making, we explore the importance of share prices, volume, volatility, and the number of market makers. Numerous studies, including Demsetz (1968), Benston and Hagerman (1974), Stoll (1978), McInish and Wood (1992), Huang and Stoll (1996) and Bessembinder and Kaufman (1997), show that dollar and percentage spreads are significantly related to these factors.

6.1. Long-run prices

We begin our analysis by exploring the importance of long-run price changes prior to the regime shifts. Benston and Hagerman (1974) find that dollar spreads are positively related to share prices. Stoll (1978) examines the relation between percentage spreads and prices and finds that percentage spreads are a declining function of price levels. Thus, the existing empirical evidence suggests that while dollar spreads increase with prices, the increase is less than proportional.

The important role of prices in previous research implies that there may be a significant decline in average prices among stocks whose market makers initiate odd-eighth quotes and an increase in average prices among stocks whose market makers withdraw odd-eighth quotes. Fig. 3 provides the average prices

[7] An alternative explanation for the association between the avoidance of odd-eighth quotes and the increase in volume is that the increase in trading activity reflects an information event that attracts more informed traders. The higher market making costs associated with the increase in informed trading trigger the withdrawal of odd-eighth quotes. However, Table 6 shows that abnormal volume is associated with both initiations and withdrawals, and an increased incidence of informed trading would not be expected to lead to reductions in spreads.

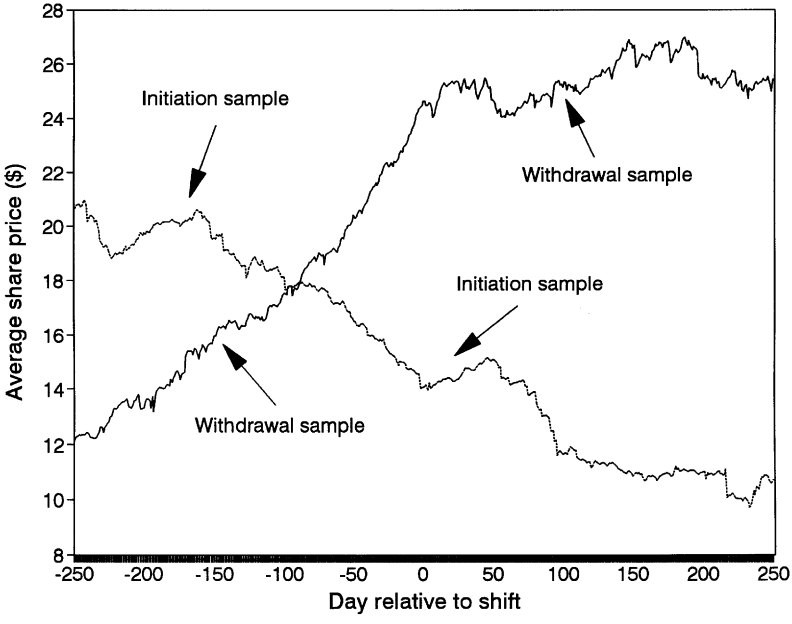


Fig. 3. The average closing prices for the 67 (58) Nasdaq issues whose market makers started (stopped) using odd-eighth quotes routinely between 1990 and 1994. Day 0 is defined as the date that odd-eighth quotes were initiated/withdrawn.

for the initiation and the withdrawal sample over the interval $[-250, 250]$. The figure shows that the average price for the initiation sample is roughly \$22 on day -250. During the following year, average prices decline significantly, falling below \$15 by day 0. Conversely, the average price for the withdrawal sample increases from \$14 on day -250 to \$25 by day 0.

The increase (decline) in average prices preceding the withdrawal (initiation) of odd-eighth quotes is consistent with the hypothesis that cumulative price changes lead dealers to initiate or withdraw odd-eighth quotes. If prices are responsible for the change in quotations, a similar price threshold might trigger the initiation and withdrawal of odd-eighth quotes. However, the average price of \$25 associated with the withdrawal of these quotes is almost double the price of \$15 associated with their initiation.

Further, the potential link between long-run changes in prices and the shift in the use of odd-eighth quotes should be interpreted with caution since our findings are subject to a sample selection bias. Our selection criterion identifies stocks whose dealers alter their frequency of odd-eighth quotes. Thus, we necessarily exclude cases in which the use of odd-eighth quotes does not change despite significant changes in the costs of making markets. For example, we

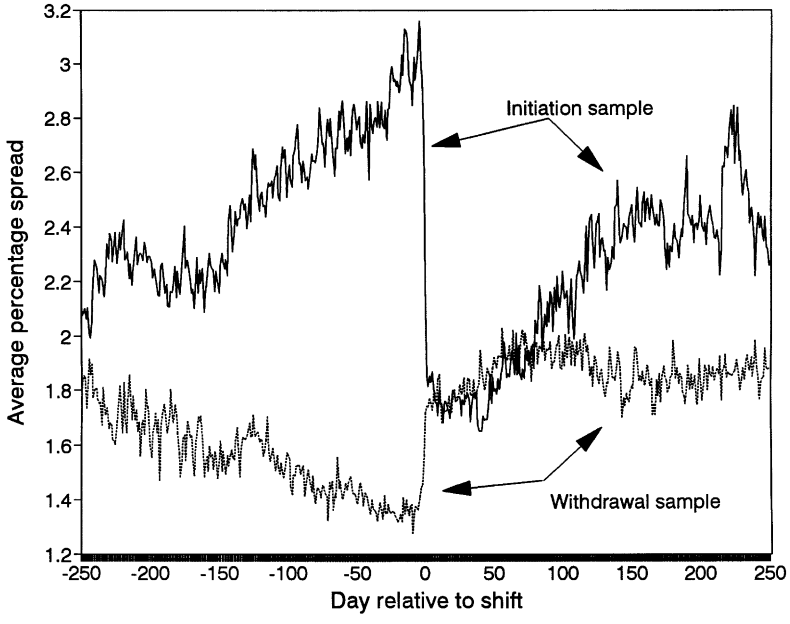


Fig. 4. A comparison of average percentage spreads for Nasdaq issues whose market makers withdrew (58 issues) or initiated (67 issues) odd-eighth quotes between 1990 and 1994. Average percentage spreads for each firm are calculated by dividing the inside dollar spread by the average of the inside bid and ask price for all quote revisions that reflect a change in either the inside bid or ask between 9:30 a.m. and 4:00 p.m. Day 0 is defined as the date that market makers initiated or withdrew their routine use of odd-eighth quotes.

exclude stocks whose dealers fail to alter their use of odd-eighth quotes despite significant changes in share prices. Therefore, our results potentially overstate the link between price changes and the use of odd-eighth quotes.

6.2. Long-run percentage spreads

The persistent decline in prices preceding the initiation of odd-eighth quotes and the equally persistent increase in prices preceding the withdrawal of these price fractions is consistent with the hypothesis that higher priced stocks have wider spreads than lower priced issues. The relation between the initiation and withdrawal of odd-eighth quotes and percentage spreads during the interval $[-250, 250]$ is depicted in Fig. 4. For each stock, we compute an average daily percentage spread using prices estimated from the midpoint of each intraday quote, and then average these percentage spreads across stocks.

For stocks whose dealers initiate odd-eighth quotes, percentage spreads increase significantly during the preceding year, rising from approximately 2.1%

on day −250 to almost 3% by day −1. Similarly, percentage spreads decline from about 1.8% to under 1.4% during the year preceding the withdrawal of odd-eighth quotes. Once odd-eighth quotes are either withdrawn or initiated, the percentage spreads converge at approximately 1.8%. Thus, the combination of long-run price changes and the initiation/withdrawal of odd-eighth quotes serves to equate percentage spreads. The two series then begin to diverge, with the percentage spreads for the withdrawal sample remaining relatively constant, and the percentage spreads for the initiation sample climbing in the face of continued price declines.

The observed relation between percentage spreads and odd-eighth avoidance or use is, as is true of many findings in economics, open to interpretation. On the one hand, Furbush and Smith (1996) suggest that the equality of percentage spreads after the initiation/withdrawal of odd-eighth quotes implies that investors are not disadvantaged when trading stocks whose market makers avoid odd-eighth quotes. On the other hand, the equality of percentage spreads across price levels is not consistent with the previous research that consistently finds a negative relation between percentage spreads and prices. Further, the similarity between the percentage spreads of higher and lower priced stocks is unexpected since the percentage spreads of lower priced stocks are artificially inflated due to the minimum tick size of \$0.125. In other words, percentage spreads for stocks trading close to, but above \$10, are elevated due to the inability to narrow inside spreads below \$0.125, even when market makers quote stocks using all available price fractions. These same constraints on percentage spreads should not be present among the higher priced stocks since the minimum tick size is not binding. Thus, the equality of percentage spreads for stocks priced between \$14 and \$24 is surprising in the context of competitive market making.

An alternative explanation for the results in Fig. 4 exploits the relation between percentage spreads and prices conditional on whether the stock is or is not quoted in odd-eighths. Specifically, we compute percentage spreads using every quote revision during the period $[-60, -1]$. Fig. 5 plots the average percentage spread for fourteen different price ranges for each of the two samples. The figure clearly shows that the negative relation between percentage spreads and price levels exists *within* our two samples preceding the shift in odd-eighths quotations.

The figure also illustrates how the act of initiating or withdrawing odd-eighth quotes reflects a jump from one negatively sloped curve to the other. Specifically, as average prices decline prior to the initiation of odd-eighth quotes, firms move to the left along the upper curve, resulting in ever increasing percentage spreads. Similarly, firms move to the right along the lower curve as average prices rise preceding the withdrawal of odd-eighth quotes. When market makers shift their use of odd-eighth quotes, the stocks jump between curves such that their percentage spreads are virtually identical. However, these percentage

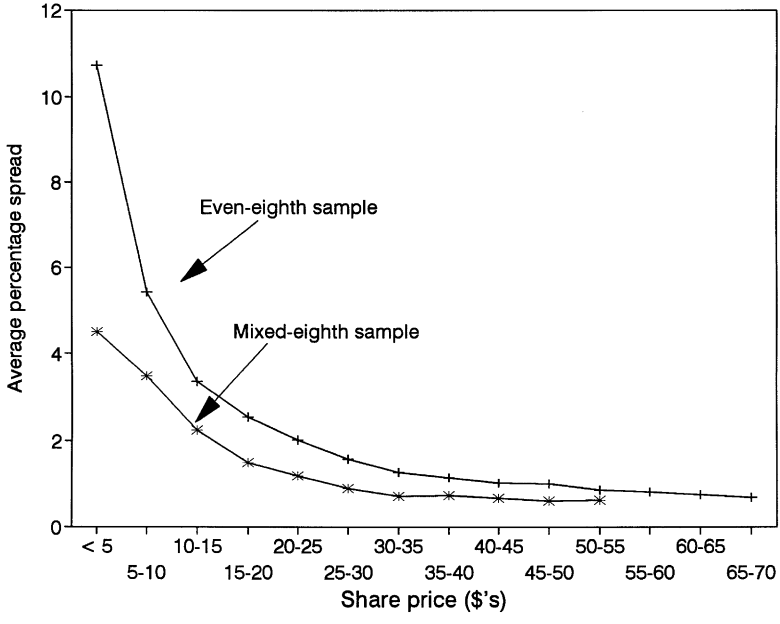


Fig. 5. The relation between average percentage spreads and share prices for the 67 (58) stocks prior to the initiation (withdrawal) of odd-eighth quotes. For each stock, we compute the percentage spread as the inside dollar spread divided by the average of the bid and ask prices for all quotes that reflect a change in either the inside bid or ask price between 9:30 a.m. and 4:00 p.m. We then average the percentage spreads within price categories for each of the two samples. The estimates are computed using inside quotes during the 60 trading days immediately preceding the initiation or withdrawal of odd-eighth quotes. The upper curve represents the average percentage spread prior to the initiation of odd-eighth quotes. The lower curve represents the average percentage spread prior to the withdrawal of odd-eighth quotes. The sample period for initiations/withdrawals is 1990 to 1994.

spreads do not reflect similar positions on the same curve, but similar percentage spreads on two separate curves. Thus, the alignment of percentage spreads following the initiation or withdrawal of odd-eighth quotes may be the result of (1) coincidence, (2) implicit collusion that is more difficult to sustain at lower share prices, or (3) a competitive adjustment of spreads to changing price levels subject to the constraints of the pricing convention. Unfortunately, our data do not permit us to conclusively determine which of these alternatives are responsible for our results.

While the specific link between prices, percentage spreads and the use of odd-eighth quotes remains unclear, these results underscore the importance of price levels in the initiation and withdrawal of odd-eighth quotes. Indeed, Christie and Schultz (1994) find that their price variable remains a significant

determinant of whether a stock was quoted in odd-eighths in their sample, even after controlling for past usage of these quotes. Fig. 5 also provides additional evidence that prices are relevant since no stock whose price exceeds \$55 is quoted in both even and odd-eighths.

6.3. Kandel and Marx hypothesis

Kandel and Marx (1997) develop a model that provides specific predictions relating prices and the frequency of odd-eighth quotes. They argue that without overt collusion, the highest sustainable spread in a dealer market is the marginal cost of a trade plus two ticks. Since the minimum tick size for Nasdaq stocks whose price exceeds \$10 is one-eighth, dealers can ensure an effective tick size of \$0.25 by coordinating their quotation patterns and avoiding odd-eighth quotes. Conversely, the minimum tick size for stocks priced under \$10 is one-thirty-second. Since odd-eighth avoidance implies a spread equal to the marginal cost plus eight ticks for stocks whose price lies below \$10, market makers would no longer be able to continue avoiding odd-eighth quotes.

Under the Kandel and Marx hypothesis, odd-eighth quotes would be initiated (withdrawn) as prices fall below (rise above) \$10. The results in Table 4 for those issues experiencing a precipitous decline in prices provide one test of this hypothesis. If the initiation of odd-eighth quotes for these four issues is consistent with the Kandel and Marx model, prices should fall from above \$10 to below \$10. An analysis of these issues provides results that are broadly consistent with this hypothesis. Specifically, the price of Life Core Biomedical fell from \$14 to \$3.25 coincident with the initiation of odd-eighth quotes. In addition, the price of Quarterdeck Office Systems fell from \$12.375 to \$5.625 on the same date that these price fractions were initiated. The prices of the other two issues fell to \$13.50 for Synergen Inc. and \$12.875 for Health Care Compare when odd-eighth price fractions were initiated.

Additional evidence on the validity of the Kandel and Marx model can be obtained by expanding our analysis to the prices for all issues on the date that odd-eighth quotes are initiated or withdrawn. Panel A (B) of Fig. 6 provides a histogram of the share prices associated with the initiation (withdrawal) of odd-eighth quotes.[8] Panel A excludes those issues in which odd-eighths are initiated coincident with the announcement of a merger or takeover.

Overall, the evidence for the Kandel and Marx model is mixed. First, consider the results for the initiation sample in Panel A. Broadly consistent with their

[8] It is important to note that our sample only permits a partial test of the predictions from Kandel and Marx (1997). Recall that we select stocks based on a significant change in the frequency of odd-eighth quotes. We therefore ignore issues whose prices experience similar declines without a change in quotation patterns.

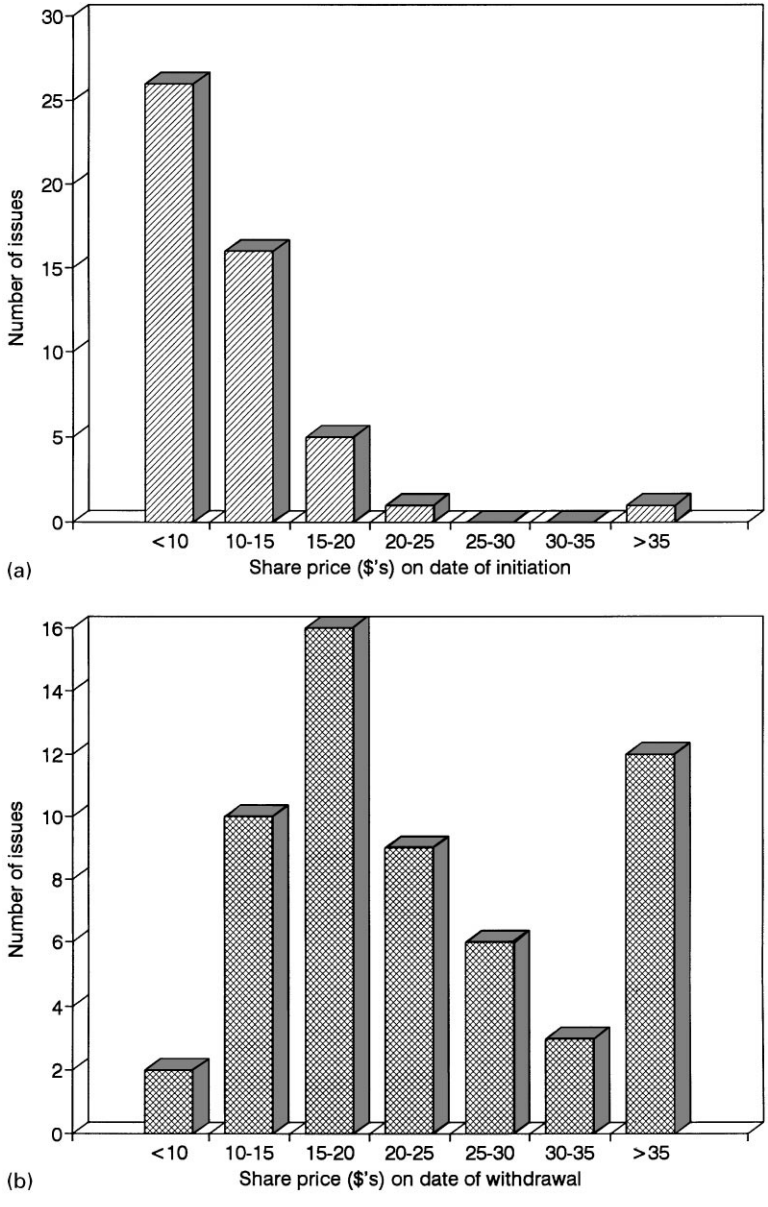


Fig. 6. The distribution of share prices on the date that odd-eighth quotes are initiated or withdrawn. For each issue, we compute the average price using the midpoint of the bid-ask spread for all quote revisions that reflect a change in either the inside bid or ask between 9:30 a.m. and 4:00 p.m. Panel A excludes those issues whose market makers initiated odd-eighth quotes coincident with the announcement of a merger or takeover. Panel A is based on 52 issues, while Panel B presents the results for the withdrawal sample of 58 issues. The sample period for initiations/withdrawals is 1990–1994.

model, odd-eighth quotes are initiated at prices under \$10 for 50% of the issues, with an additional 30% occurring among stocks with prices between \$10 and \$15. In addition, prices fall below \$10 shortly before the change in quotation patterns for 14 of the 26 issues whose price initiation date price is under \$10.[9] However, the Kandel and Marx model cannot explain other results. For example, stock prices never exceed \$10 on any of the 60 trading days preceding the initiation of odd-eighth quotes for 25% of the issues with an initiation price under \$10. The maintenance of a spread of eight ticks for at least the previous three months is inconsistent with their hypothesis. In addition, the prices for 14 of the 16 stocks whose prices lie between \$10 and \$15 on the initiation date never slip below \$10 during the preceding 60 trading days.

Panel B, which presents the evidence for the withdrawal sample, provides even less support for the Kandel and Marx prediction that odd-eighth quotes are withdrawn shortly after prices rise above \$10. The figure shows that odd-eighth quotes are withdrawn across all price categories, with the second highest concentration of prices exceeding \$35. The absence of a systematic association between the \$10 hurdle and the prices when odd-eighth quotes are withdrawn implies that their model cannot explain these results.

The Kandel and Marx hypothesis cannot however, be dismissed on the basis on these results. Recall that their model calls for the maintenance of spreads equal to marginal costs plus two ticks. While two ticks translate into minimum spreads of \$0.25 for prices in excess of \$10, we may not have accurately controlled for the marginal costs of trading. Thus, the delay in withdrawing odd-eighth quotes for the higher priced stocks may simply reflect higher marginal trading costs for these issues that we do not capture. In addition, there may be fixed costs associated with switching between quotation regimes that discourage market makers from altering their quotation practices immediately upon the movement of prices about \$10, such as the degree of interdependence implied by the Excess Spread Rule.

6.4. Turnover

The final variable that we consider in our search for long-run cost-based explanations for the change in quotation patterns is volume. Stocks with higher volume permit market makers greater latitude to control inventory since there are likely other parties willing to trade at any given time. Thus, we would expect that stocks whose market makers initiate (withdraw) odd-eighth quotes would be characterized by increases (decreases) in volume preceding the shift in odd-eighths usage.

[9] Bessembinder (1997b) also finds evidence that is consistent with the Kandel and Marx (1997) hypothesis in his study of Nasdaq stocks whose prices are near \$10.

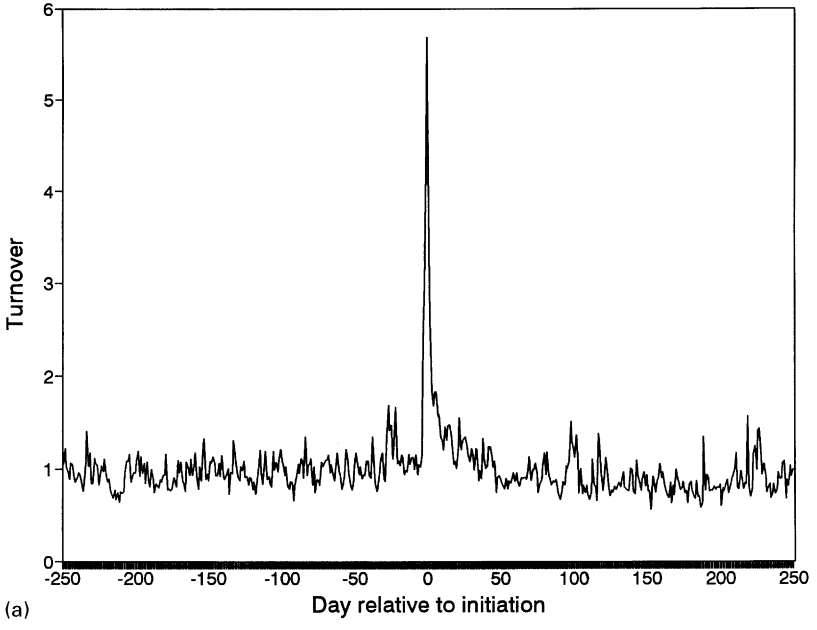
Our evidence on the importance of long-run changes in volume is presented in Fig. 7. For each stock, we compute the daily turnover, defined as the total share volume scaled by the number of shares outstanding (obtained from CRSP). We then average the turnover values across stocks within each sample, and plot the average turnover for the period [− 250, 250]. Panel A (B) presents the results for the initiation (withdrawal) sample. Panel A excludes any issue associated with a merger announcement to abstract from the volume affects associated with these corporate control events. The results for the initiation sample indicate that although there is a large spike of trading activity surrounding the shift to the regular use of odd-eighth quotes, no upward trend is apparent during the preceding year. Thus, the initiation of odd-eighth quotes does not appear to have arisen from an increase in volume. Panel B, which provides the results for the withdrawal sample, does display a significant increase in volume preceding the change in quotation pattern, and a general leveling off of turnover for the ensuing 6 months. However, the time-series of volume is moving in the opposite direction from what we would have predicted for the withdrawal sample, since spreads are widening after a period of sustained increases in volume.[10]

7. The number of market makers

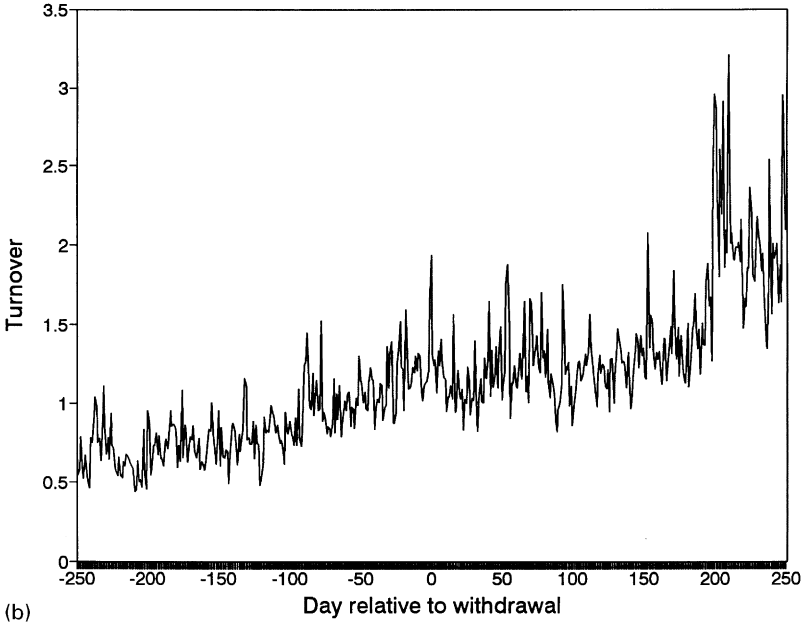
This paper has shown that dollar and percentage spreads are significantly impacted when odd-eighth quotes are initiated or withdrawn. Further, the change in trading costs faced by investors due to the widening or narrowing of spreads is not generally associated with equally abrupt changes in the costs of market making. These results imply that the change in quotation patterns has an important impact on the profitability of making markets in these stocks. For example, dollar and percentage spreads fall by over 30% when odd-eighths are initiated. If spreads reflect a competitive equilibrium prior to the initiation of odd-eighth quotes, the higher-cost market makers would be forced from the market after spreads narrow. Conversely, the number of market makers would deteriorate prior to the withdrawal of odd-eighth quotes if the pre-withdrawal spreads are not sufficient to cover the costs of market making.

Fig. 8 plots the average number of market makers for the initiation and withdrawal samples over the interval [− 250, 250]. Consistent with our evidence from Section 5.3, Panel A shows that the average number of market makers increases sharply during the period immediately surrounding the initiation of

[10] We also studied the time series of return volatilties during the period [− 250, 250], where volatility was measured weekly using the variance of daily closing prices. These results (not reported) show that volatility displays no tendency to increase or decrease prior to the shift in quotation pattern.


Turnover
0
1
2
3
4
5
6
-250
-200
-150
-100
-50
0
50
100
150
200
250
Day relative to initiation

(a)


Turnover
0
0.5
1
1.5
2
2.5
3
3.5
-250
-200
-150
-100
-50
0
50
100
150
200
250
Day relative to withdrawal

(b)

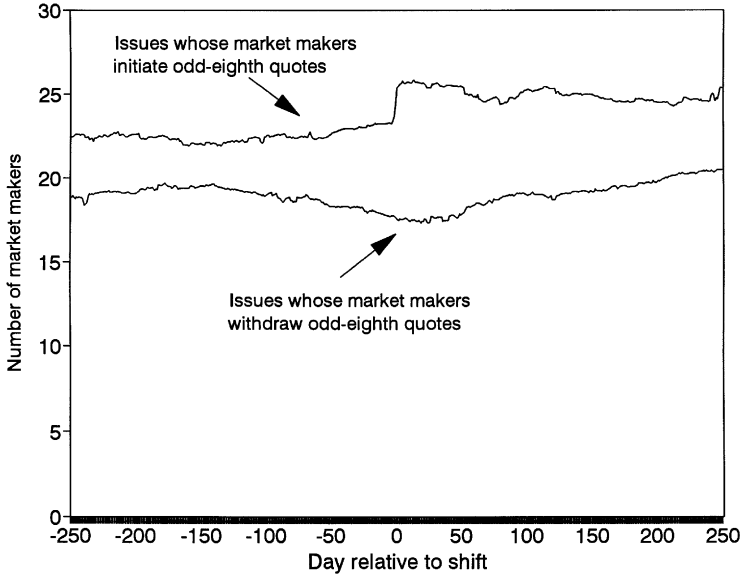


Fig. 8. The average number of market makers for the sample of 67 (58) issues whose market makers started (stopped) using odd-eighth quotes routinely between 1990 and 1994. Day 0 is defined at the date that odd-eighth quotes were initiated/withdrawn.

odd-eighth quotes.[11] However, we do not observe a decline in the average number of market makers in the year following the narrowing of spreads. The willingness of dealers to make markets when profits decline so dramatically is consistent with the hypothesis that inside spreads are not fully competitive prior to the introduction of odd-eighth quotes.

The time-series of the average number of dealers for the withdrawal sample is shown in Panel B. While there is a slight decline in the average number of dealers prior to the withdrawal of odd-eighth quotes, the exodus of one market maker does not appear to warrant an increase in spreads of nearly 50% for the

[11] The increase in the number of dealers in Table 6 is lower than the increase depicted in Fig. 8. Table 6 excludes those stocks that merged, while Fig. 8 uses the complete sample.

Fig. 7. The time-series of average daily turnover for the stocks whose market makers initiated/withdrew odd-eighth quotes between 1990 and 1994. For each issue, we compute the turnover, defined as the daily share volume divided by the number of outstanding shares, between days -250 and 250, where day 0 is defined as the date that odd-eighth quotes are initiated or withdrawn. Panel A excludes those issues whose market makers initiated odd-eighth quotes coincident with the announcement of a merger or takeover. Panel A presents the results for the 52 initiation issues, while Panel B presents the results for the withdrawal sample of 58 issues.

remaining dealers. Thus, Fig. 8 provides little evidence that the changes in trading costs resulting from the widening or narrowing of spreads is necessary to restore trading costs to competitive levels.

One interesting result in Panel B is that the average number of dealers increases by less than 10% in the year following the withdrawal of odd-eighth quotes. Our evidence suggests that the profitability of making markets is these stocks increases after the withdrawal of odd-eighth quotes since the costs of market making do not appear to increase significantly. It is perhaps surprising that these issues don't attract a larger number of market makers. While our data are unable to resolve this issue, the conclusions of Huang and Stoll (1996), Godek (1996) and Kandel and Marx (1997) imply that potential entrants may be dissuaded from making markets in these issues by an inability to capture order flow due to the high incidence of preferencing among existing market makers. In light of these results, further study of the relation between the profitability of market making and the equilibrium number of dealers appears worthwhile.

8. Summary and conclusions

The discovery by Christie and Schultz (1994) that Nasdaq market makers avoid odd-eighth quotes in large, actively traded stocks has stimulated academic research (see Schwert, 1997), investigations of Nasdaq by the Department of Justice and the Securities and Exchange Commission, and the implementation of new rules governing trading (see Barclay et al., 1999). One of the most intriguing findings uncovered by the Government is the presence of a standard, or an 'ethic', dictating that odd-eighth quotes are only considered acceptable when individual dealers post bid–ask spreads of less than \$0.75.

This paper extends this dialogue by studying 67 (58) Nasdaq stocks whose market makers initiate (withdraw) the regular use of odd-eighth quotes between 1990 and 1994. These regime shifts are very swift, with multiple dealers altering their quotation patterns within the course of a few days, and often within the span of a few hours. These results are especially intriguing among the sample of stocks whose market makers suddenly restrict themselves to even-eighth quotes after routinely quoting the stock using both even and odd eighths, since this regime shift would appear to require a degree of coordination among the market participants. We find that the transition between regimes results in dramatic changes in both quoted and effective spreads.

In light of the decisive change in trading costs faced by investors after market makers alter their quotation patterns, we might expect to observe similarly dramatic changes in factors that affect the costs of making markets. We find that for approximately one-third of the sample, market makers initiate the regular use of odd-eighth quotes coincident with the announcement of a merger or a steep decline in prices. For the other issues, we are unable to identify any event

that would precipitate a decline in spreads of close to 40%. We met with even less success among the sample of stocks whose dealers withdraw odd-eighth quotes. Thus, market makers do not appear to alter their quotation patterns in response to shocks to the costs of making markets. Whatever the triggering event, it is considerably more subtle than the resulting impact on trading costs faced by investors after the change in quotation patterns.

In the absence of a short-run explanation for the shift in quotation regimes, we broaden our search to include long-run changes in variables such as prices, volume, volatility, and the number of market makers. The one persistent pattern that emerges is that odd-eighth quotes are initiated after a prolonged period of average price declines, and are withdrawn after a similarly protracted period of price appreciation. One hypothesis is that market makers adjust their quotation patterns to compensate for the long-run price changes and realign percentage spreads. The combined effects of initiating odd-eighth quotes among lower priced stocks and removing these price fractions among higher priced stocks serves to re-align percentage spreads at the date of the shift in odd-eighths use. However, numerous studies confirm that prices and spreads are not proportional, and that percentage spreads decline with prices. Adjusting quotation patterns to keep percentage spreads constant across price levels is not consistent with our prior understanding of these markets. Unfortunately, the exact relation between prices, spreads, and the pricing convention is elusive, and certainly worthy of additional research to help disentangle the possible sources of causation. In addition, our results may overstate the importance of price levels, since there may well exist a number of cases where large price changes occur in the absence of a shift in quotation pattern.

Alternative explanations for the initiation/withdrawal of odd-eighth quotes include Kandel and Marx (1997) and Christie and Schultz (1994). In each of these models, market makers are presumed to use odd-eighth quotes as a means of earning supra-competitive spreads, in one case as a function of the tick size, the other through tacit collusion. In the Kandel and Marx (1997) model, abrupt shifts in quotation patterns may occur as stock prices move near \$10 and the tick size varies between one-thirty-second (for stocks priced under \$10) and one-eighth (for stocks priced above \$10). Christie and Schultz (1994) do not specify the conditions under which implicit agreements materialize or disintegrate, although it is reasonable to presume that agreements to inflate bid–ask spreads are more easily disguised among higher priced stocks. This paper does not afford us the opportunity to directly examine this hypothesis, although we have established the circumstances (or lack thereof) under which these regime shifts occur.

Today, the Nasdaq market differs in important ways from the period we study, including the display of public limit orders and superior quotes placed in private trading systems (see Barclay et al., 1999). However, our results highlight the ability of multiple dealers to coordinate their quotes in ways that are not at all transparent, but that have a significant impact on trading costs.

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