CLUSTERING AND COMPETITION IN ASSET MARKETS*

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ABSTRACT

Economists, financial commentators, regulatory agencies, and the legal community have recently criticized the Nasdaq Stock Market, Inc., because there is greater clustering of stock quotations on even-eighths on Nasdaq than on the New York Stock Exchange or the American Stock Exchange, a phenomenon which critics attribute to collusion or some other defect in Nasdaq market structure. However, as this article demonstrates, clustering occurs in varying degrees in many other incontestably competitive financial markets, including the NYSE, the AMEX, the London Stock Exchange, the London gold market, and the international foreign exchange market. This article provides a competitive theory of clustering that emphasizes the effect of uncertainty, the size of transactions, volatility, and the informational and transactional roles of quotations on the degree of clustering. In addition, the article examines how market structure can affect the degree of clustering and considers the relation between clustering, spreads, and investors' transactions costs.

I. INTRODUCTION

Most stocks listed on the Nasdaq Stock Market, Inc. (Nasdaq), the New York Stock Exchange (NYSE), and the American Stock Exchange (AMEX) (collectively NYSE/AMEX) are quoted in increments of one-eighth. While even-eighth quotes are favored on both systems, odd-eighth quotes are used far less often for stocks listed on Nasdaq than for stocks listed on NYSE/

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AMEX.[1] This phenomenon has drawn great attention from economists, financial commentators, regulatory agencies, and the legal community.[2] The common view is that the greater degree of clustering on Nasdaq occurs because of some defect in Nasdaq market structure. Some have suggested that the only plausible explanation for this pattern is price fixing by colluding market makers on Nasdaq; this view has been reinforced by a belief that Nasdaq clustering disappeared following news reports about clustering and the collusion hypothesis.[3] Others have argued that the absence of time priority rules on Nasdaq is to blame.[4]

The widespread view that Nasdaq clustering is the by-product of defective market structure and/or collusion is surprising because clustering occurs in varying degrees in many other financial markets, including AMEX, NYSE, the London Stock Exchange, the London gold market, and the international foreign exchange market, as we demonstrate below. The prevalence of clustering in so many other markets, many of them incontestably competitive by any standard, is fundamentally inconsistent with the collusion hypothesis.

In this article, we provide what the existing literature lacks—a competitive theory of clustering. We also examine how market structure can affect the degree of clustering. For example, we show that the relatively higher degree of clustering on Nasdaq relative to NYSE/AMEX can be attributed to the NYSE/AMEX market structure in which customers can place limit orders and quasi-monopolist "specialists" have responsibility for maintaining price continuity. In fact, our findings suggest that if anything is anomalous, it is not the degree of clustering on Nasdaq, which resembles other highly competitive markets, but the muted clustering on NYSE/AMEX.

The remainder of this article is organized as follows. In Section II, we provide a competitive explanation for clustering in financial markets and describe the determinants of the extent of clustering. In Section III, we pro-

[1] The frequency of quotes at each odd-eighth exceeds 10 percent for NYSE/AMEX stocks but is less than 4 percent for Nasdaq stocks. Seventy percent of Nasdaq stocks have fewer than 25 percent of inside quotes which contain an odd-eighth. W. Christie and P. Schultz, *Why Do NASDAQ Market Makers Avoid Odd-Eighth Quotes?* 49 J Fin 1813, 1820–21 (1994).

[2] After news reports about Christie and Schultz appeared, more than 20 class-action lawsuits were filed in various federal courts alleging price rigging by dozens of leading brokerage firms. The U.S. Department of Justice and Securities and Exchange Commission have also announced inquiries into trading practices on Nasdaq.

[3] W. Christie, J. Harris, and P. Schultz, *Why Did NASDAQ Market Makers Stop Avoiding Odd-Eighth Quotes?* 49 J Fin 1841 (1994).

[4] P. E. Godek, *Why Nasdaq Market Makers Avoid Odd-Eighth Quotes,* J Fin Econ (1996) (in press); also, see Christie and Schultz, at 1837 (cited at note 1).

vide empirical support for the competitive theory of clustering by analyzing intermarket and cross-sectional variation in the extent of clustering. This analysis highlights the critical role of differences between the structure of NYSE/AMEX and the structure of dealer markets like Nasdaq. The next two sections critically examine the collusion hypothesis. Section IV critically examines the collusion hypothesis in light of the theory of industrial organization, and Section V analyzes and rejects the claim that an implicit pricing agreement "collapsed" following news reports about the collusion hypothesis. Section VI examines the relation between the clustering, spreads, and investors' transactions costs. Our conclusions appear in Section VII.

II. A Theory of Clustering

In ordinary markets, the unit of currency usually establishes the minimum possible unit of trade, whereas in organized financial markets, the minimum possible unit of trade, known as the minimum tick, is often established by regulation. The minimum possible unit of trade, however, need not be the actual unit of trade used by market participants. For example, even though housing prices could be negotiated down to the penny (the minimum possible unit of trade for dollar-denominated goods), offers, counteroffers, and transactions in the housing market typically are based on a $1,000 unit of trade, a unit far greater than the minimum.[5]

Finer units of trade allow for more accurate pricing. But this is a mixed blessing. It takes time and effort to obtain more precise valuations of assets. Because the number of possible outcomes increases as the unit of trade becomes finer, the number of possible offers and counteroffers in negotiated transactions also increases. The expected time it takes for negotiations to converge rises, increasing the price risk to which market participants are subjected during the negotiations. The larger the number of possible outcomes, moreover, the greater the likelihood that offers and counteroffers will be misunderstood.

For these reasons, a grid of possible transactions prices much coarser than the set of all real numbers can be beneficial. The precise degree of coarseness chosen will depend on the balance between the benefits and costs of a finer grid. Once this is understood, several predictions about the unit of trade used in asset markets follow directly.

[5] To verify this casual empiricism, we studied all residential real estate sales in Chicago in January 1995 involving amounts in excess of $10,000 as reported by the *Realty Sales Guide*. We found that 69.1 percent of the 1,827 transactions had prices in units of $1,000 and an additional 14.1 percent had prices in units of $500. The average price was $125,184, and the median price was $105,500.

First, we would expect a coarser unit of trade when the value of assets is unknown and precise valuation is difficult or costly. Thus, a coarse unit of trade is typical of housing markets in which the heterogeneity of houses and the possibility that the owner has adverse private information about the value of his property cause appraisals to be costly and imprecise. In liquid markets, by contrast, the units of trade are finer because the value of an asset is more easily ascertained when buyers and sellers are continually trading. Of course, even in liquid markets, we would expect a coarser unit of trade for higher-priced assets because any given unit of trade is a smaller percentage of the value of such assets. This explains why coarser units of trade are typically used for higher-priced securities.

We would also expect to find coarser units of trade when prices are volatile because precise valuations are more difficult and costly to obtain in volatile markets. Precise valuations may also be less valuable when prices change rapidly, thereby making valuations untimely. Even when precision is possible, moreover, price volatility may lead to coarse units of trade because market participants will want to reduce their exposure to risk by transacting quickly rather than waiting to perform a precise valuation. A coarser unit of trade allows negotiations to converge quickly. If a seller asks, say, $85,000 for a house and a bidder offers $80,000, a $1,000 trading unit reduces to four the number of possible offers and counteroffers. (The possible offers and counteroffers are $81,000, $82,000, $83,000, and $84,000.) With fewer possible offers and counteroffers, negotiations can converge to an acceptable price more quickly than if participants in the negotiation sought to refine their valuations down to the penny.

Finally, we would expect coarser units of trade when the total gains counterparties expect to obtain from trading are small. Under these circumstances, the benefits of greater accuracy then are not worth the costs of obtaining more precise valuations and negotiating more precise prices. This explains why small investors often do not negotiate securities transactions and institutional investors (who trade larger quantities) do.

These considerations are important for designers of securities markets in selecting a minimum tick—the smallest possible unit of trade used by the market. The optimal minimum tick will be smaller than the unit of trade typically used during periods of normal trading activity. If market participants typically used the minimum tick as the unit of trade, then the market would lack the flexibility to reduce the minimum tick to allow for smaller units of trade when appropriate.[6] The minimum allowable increment is not

[6] This explains why the minimum allowable tick on Nasdaq and other stock markets is smaller for low-priced stocks for which the customary minimum tick of one-eighth does not allow for sufficient pricing precision. For a discussion of the optimal minimum tick, see L.

chosen to be the typical degree of precision required but, rather, to reflect the most precision required, that is, the relatively rare event.[7]

To understand the implications of the theory of clustering for the distribution of quotes, it is important to recognize that quotes in asset markets have both an informational role and a transactional role. Quotes have an informational role because they tell market participants about the identity of potential counterparties and provide some indication as to the price at which an asset can be bought or sold. For example, in the housing market, sellers often quote an asking price; this allows potential buyers to determine which houses are for sale and whether a particular house is likely to be in the buyer's price range. Similarly, in securities markets, quotes allow market participants to determine which of many possible market makers are seriously interested in dealing in any particular security and whether it is desirable to trade at some price near the quoted price.

Quotes also have a transactional function because trades can occur at the quoted prices in many markets. For example, in the housing market, buyers could offer to purchase a home at the seller's posted price, resulting in a transaction. When quotes take the form of offers and counteroffers in negotiations, the negotiations end when one party accepts the other's offer. And, in securities markets, market makers are sometimes allowed or required to post quotes that are good for some specified quantity. These quotes have a transactional role because market participants can "hit" bids and "lift" offers, resulting in trades. Limit orders are another form of quotes with a transactional function.

When quotes have a purely informational role, extremely precise quotes are unnecessary. The primary role of such quotes is to tell customers that the market maker is, in fact, in the market. Precision is of little value, particularly when market conditions may change between the time a quote is made and the time a customer contacts the market maker to negotiate a transaction. Precision is costly, moreover, because transmitting and displaying accurately more precise numbers is costly. A trader calling out information to his clerk about what prices to bid or offer might find it uneconomically time consuming to call out this information to several digits of accuracy. More errors also occur when more digits are communicated. These considerations all suggest that quotes that serve a purely informational role are likely to be made using imprecise units of trade, resulting in clustering.

Harris, *Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes,* 7 Rev Fin Stud 149 (1994).

[7] For additional discussion of the optimal tick size, see S. Brown, P. A. Laux, and B. Schachter, *On the Existence of an Optimal Tick Size,* 10 Rev Fut 50 (1991).

Quotes have an informational role even in markets in which market participants may trade at the posted price because quotes communicate that the market maker is not only in the market and willing to trade the posted quantity at the posted price but also that he may be willing to trade quantities larger than the posted quantities at prices near the posted price (or perhaps trade the posted quantities at more favorable prices). The transactional role of quotes in these markets may affect the distribution of quotes, however. On the one hand, market makers who make better quotes may have an increased probability of execution because when someone who wants to transact immediately appears, he will want to trade at the best quoted price. However, market makers who post the best quotes also bear the risk that they will have to trade at the posted quote when market conditions change and active market participants place orders before the market maker can revise his quote.[8] Trades at undesirable prices also may occur when the market maker receives orders from informed investors who recognize that the posted quotes are favorable to them. This "free option" problem created by the possibility of transactions at the posted quotes increases the costs of precision.[9]

Many of the considerations that we believe affect the choice of a unit of trade (such as uncertainty, liquidity, and risk) have been widely recognized as determinants of spreads. In our analysis, the spread between bid and offer quotes will typically exceed the minimum tick because quotes are made using the customary unit of trade, which typically exceeds the minimum tick. Thus, spreads will be wider when the value of assets is less certain, when there is less liquidity and when there is more price risk. In markets where quotes serve a transactional as well as an informational role, spreads often may be wider still because of the free option problem, particularly when market makers are required to post quotes that are good for large quantities.

Our analysis explains why clustering can occur in competitive markets. In our analysis, the degree of clustering depends upon uncertainty, liquidity, risk, and the informational and transactional role of quotes. Because these factors may vary across markets, among assets, and over time, the degree of clustering may vary as well.

[8] The "SOES Activist" problem is an example of this phenomenon. The SOES system on Nasdaq obligates dealers to execute as many as five orders for a normal unit of trading at his posted bid and ask price. The SOES activists monitor competing market makers in a stock and execute trades against any dealer whose quotes do not adjust quickly when market conditions change.

[9] For a discussion of free trading options created by market structure, see, for example, H. R. Stoll, *Principles of Trading Market Structure,* 6 J Fin Services Res 75, 84 (1992).

III. Variation in Clustering Across and Within Markets

For most stocks listed on NYSE/AMEX and Nasdaq, the minimum tick for quotations for most securities is one-eighth. Hence, the fractional portion of all quotes must be some multiple of one-eighth ranging from 0 to 7/8. Absent clustering, each fraction would occur with equal probability (12.5 percent) and even-eighths (i.e., 0, 1/4, 1/2, and 3/4) would be as common as odd-eighths (i.e., 1/8, 3/8, 5/8, and 7/8). However, clustering is common, and the extent of clustering varies both across and within markets.

A. *Intermarket Variation in Clustering*

Critics of Nasdaq clustering appear to assume that the lesser degree of clustering on NYSE/AMEX is the normal result of competition, and the higher degree of clustering on Nasdaq is anomalous and indicative of a collusive marketplace. To test this assumption, we have studied the degree of clustering in several other large and successful financial markets. As we explain below, every market we have studied has substantially more clustering than is observed on NYSE/AMEX.[10]

1. *London Stock Exchange (LSE).* The LSE's Stock Exchange Automated Quotation System (SEAQ) is an open electronic quotation system that operates very much like Nasdaq. Competing market makers on SEAQ post bid and ask prices for guaranteed quantities. The SEAQ also displays trade information, although brokers and dealers negotiate trades by phone. Generally, quotes for stocks listed on the SEAQ are expressed in units of pounds and pence (there are 100 pence to the pound); the conventional minimum quotation interval is one penny.[11] The LSE has been very successful: four

[10] Clustering in other markets has been reported by a number of authors. M. F. M. Osborne, *Periodic Structure in the Brownian Motion of Stock Prices,* 10 Operations Res 345 (1962); V. Niederhoffer, *Clustering of Stock Prices,* 13 Operations Res 258 (1965); and L. Harris, *Stock Price Clustering and Discreteness,* 4 Rev Fin Stud 389 (1991); all report clustering of NYSE/AMEX transactions prices. C. Ball, W. N. Torous, and A. E. Tschoegl, *The Degree of Price Resolution: The Case of the Gold Market,* 5 J. Fut Markets 29 (1985), describe clustering in the gold market. Clustering in the Treasury Bill Futures Market has been reported by C. Dale, *Brownian Motion in the Treasury Bill Futures Market,* 16 Bus Econ 47 (1981). Clustering has also been reported in the commodity futures market by R. Stevenson and R. Bear, *Commodity Futures: Trends or Random Walks?* 25 J. Fin 65 (1970). Finally, C. Goodhart and R. Curcio, "The Clustering of Bid/Ask Prices and the Spread in the Foreign Exchange Market" (working paper, London School of Economics, 1991) report clustering of quotes in the foreign exchange market.

[11] There are some differences between Nasdaq and SEAQ. First, there is no established minimum tick on the LSE, and a few stocks are sometimes quoted in units smaller than one penny. However, most LSE stocks trade only in units of one penny, illustrating the principle that the actual unit of trade generally exceeds the minimum possible unit of trade. In addition, SEAQ, unlike Nasdaq, does not have a special system like SOES for executing small orders. As we have explained, the existence of SOES increases the degree of clustering and the width of spreads because it emphasizes the transactional role of quotes.

times as many issuers are listed on the LSE as on any other European stock market, and the total volume of trading on the LSE exceeds the combined volume of all other European stock markets.

To examine the extent of clustering on SEAQ, we obtained and analyzed all inside quotes posted in October 1994 for stocks categorized as "liquid" by the LSE.[12] Figure 1 displays the distribution of the last digit of these quotations. Absent clustering, one would expect each digit from 0 to 9 to occur with equal frequency, that is, in 10 percent of all quotes. Instead, the data show that there is substantial clustering of quotes for stocks traded on LSE. Quotes ending in 0 and 5 are most likely to occur; each occurs in approximately 14 percent of all quotes. Quotes with last digits of 2, 3, 7, and 8 (which would obtain if dealers split units of 5 in half and rounded the resulting units of 2.5 up or down) are the next most likely to occur; each with a frequency of about 11 percent. Quotes ending in 1, 4, 6, or 9 pence are the least likely to appear; each has a frequency of about 7 percent.[13]

The extent of clustering can also be summarized numerically. One possible measure is the range between the highest and lowest quotation frequencies. To facilitate comparisons of different markets, a standardized range can be computed by dividing the range by the expected quotation frequency per unit, absent clustering.[14] The NYSE/AMEX range and standardized range is approximately .03 and .24 (= .03 divided by the expected quotation frequency, absent clustering of .125), respectively, and Nasdaq's range and standardized range is approximately .17 and 1.36, respectively.[15] Our data show a range and standardized range for the LSE of .07 and .70, showing the LSE to have more clustering than NYSE/AMEX but less clustering than Nasdaq.

2. *London Gold Market.* Representatives of firms that form the London gold market meet twice each business day and determine (or "fix") a price that clears the market, which includes customers' orders from the entire world. Prices at a fixing are established by adjusting an initial proposed fix until there is neither excess supply nor excess demand. The minimum tick

[12] To be considered "liquid" a stock's average daily volume must exceed an exchange-established benchmark. Approximately 60 percent of listed stocks are classified as "liquid." Because precise valuations are easier when stocks are liquid, we would expect these stocks to have less clustering than other stocks listed on the LSE.

[13] Our sample of more than 300,000 quotes is so large that the probability that random chance explains differences in quotation frequency is extremely remote.

[14] The standardized range is an ordinal measure which can be used to rank the degree of clustering on different markets but cannot be used to assess the relative amount of clustering on different markets.

[15] These figures are based on data presented in Christie and Schultz, at 1823 (cited at note 1).

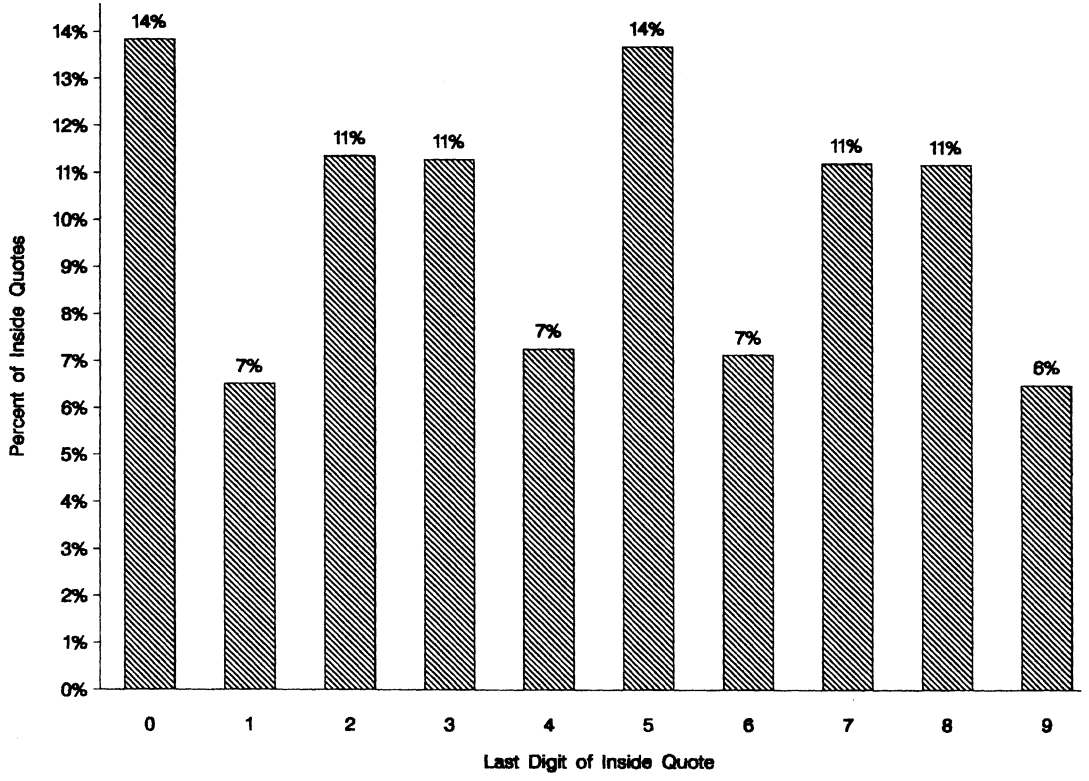

FIGURE 1.—Distribution of last digit of inside quotes: stocks listed on the London Stock Exchange, October 1994. This figure displays the distribution of the last digit of inside quotes posted in October 1994 on the Stock Exchange Automated Quotation System (SEAQ) for stocks categorized as "liquid" by the LSE. (To be "liquid," a stock's average daily volume must exceed an exchange established benchmark.) The last digit of any quote ranges from zero to nine pence. The figure excludes quotes that were in units finer than the conventional minimum quotation unit of one penny, amounting to 4.4 percent of the data. (These also cluster, as 61 percent of the quotes are in units of 0.50 pence.) The remaining data consist of 338,304 quotes on 1,259 stocks and were provided by the LSE.

permitted at a fixing is $0.05. To examine whether clustering occurs in the London gold market, we obtained data on prices for morning and afternoon fixings during the period from January 1990 to December 1994 from Data Resources, Inc./McGraw Hill.

Figure 2 shows the distribution of last digits for these fixings. These data provide strong evidence of clustering in the London gold market. A last digit of 0 is most likely to occur, appearing in about 10 percent of all fixings. A last digit of .50 (the amount one would obtain by dividing 1.00 in half) is next most likely to occur, appearing in about 9 percent of all fixings. Last digits of .25 and .75 (as would obtain when dividing .50 in half) are the next most likely to occur, each appearing in about 7 percent of all fixings. After this, last digits ending in the remaining units of .10 (i.e., .10, .20, .30, .40, .60, .70, .80, and .90) are next most likely to occur, each appearing with varying frequencies of approximately 4.5 to 6.5 percent of all fixings. Last digits ending in the remaining units of .05 (i.e., .05, 15, .35, .55, .65, .85, and .95) are least likely to appear; none occurs with a frequency of more than about 3 percent.

The range between the most common and least common ticks is about .07. Because the expected tick frequency, absent clustering, is .05, the standardized range is 1.4. Thus, the London gold market has more clustering than Nasdaq, the LSE, or NYSE/AMEX.[16]

3. *International Foreign Exchange Market.* The international foreign exchange, or FX, market is the largest financial market in the world; it has been estimated that about $1 trillion in foreign exchange transactions occurs each business day. Most transactions are carried out between banks and trading houses located in many different countries. Market participants post quotes on electronic systems and typically execute trades via telephone. Transactions typically involve dollars, marks, or yen and are quoted in decimal increments (for example, 90.05 yen per dollar).

To determine whether clustering occurs in this market, we studied quotations during the period October 1992 to September 1993 involving yen for dollars, marks for dollars, and yen for marks. Our data contain approximately 1.9 million bid and ask quotations made by several hundred major banks and brokers. These quotations were originally published by Reuters and were obtained from Olsen and Associates. By convention, quotations for trades of yen for dollars or dollars for yen are quoted in units of yen

[16] Obviously, the minimum tick in stock markets is generally a much larger percentage of the price of stocks than the minimum tick in markets such as the London gold market or the currency markets we discuss below. However, because the size of transactions is typically far larger in these markets, this does not mean that the extent of clustering is of lesser economic significance.

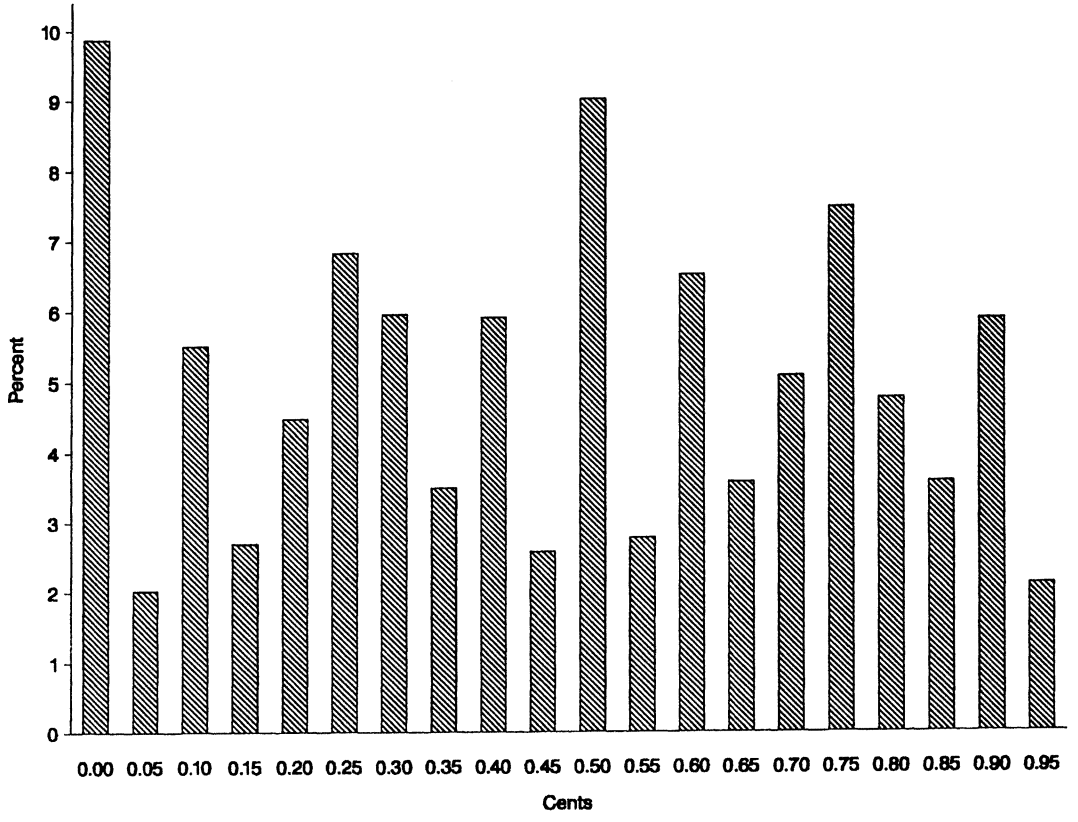

FIGURE 2.—Distribution of price fractions in the London gold market, January 1990–December 1994. The figure displays the distribution of the last two digits of clearing prices (or "fixings") in the London gold market. As fixings are in dollars, the last two digits are in cents. The information reported includes all morning and afternoon fixings for the period from January 1990 to December 1994. Each bar represents the percentage of fixings with the indicated last two digits. The data were obtained from DRI/McGraw Hill.

per dollar to two decimal places (such as 119.90 yen per dollar). Quotations for trades of yen for marks or marks for yen are quoted in units of yen per mark to two decimal places (such as 84.90 yen per mark). Quotations for trades of dollars for marks and marks for dollars are in units of marks per dollar to four decimal places (such as 1.4142 marks per dollar). Figures 3, 4, and 5 show the distribution of the last digit of yen-dollar, mark-dollar, and yen-mark quotations, respectively. These figures demonstrate that foreign exchange quotes show a strong tendency to cluster.

Absent clustering, one would expect each digit to appear with equal frequency (that is, 10 percent of all quotes). Instead, as Figure 3 shows, over 50 percent of all yen-dollar quotes are in multiples of .05 (such as 90.05 and 90.10). Fewer than 4 percent of quotes fall on decimals with a last digit of 1, 4, 6, or 9, which is comparable to the finding that fewer than 4 percent of Nasdaq quotes fall on each odd-eighth. Last digits of 2, 3, 7, and 8 occur somewhat more frequently. The data suggest that dealers usually make quotes in multiples of .05 but sometimes split the .05 in half, rounding the .025 up or down to generate a quote ending in 2, 3, 7, or 8. Occasionally, a dealer may split the difference again to obtain a last digit of 1, 4, 6, or 9. A similar pattern appears for the dollar-mark quotes in Figure 4 and for the yen/mark quotes in Figure 5, although yen/mark clustering is less marked.

For dollar-yen quotes, the range and standardized range between the most and least frequent ticks is approximately .24 and 4.8, respectively. For dollar-mark quotes, the figures are approximately .20 and 4.0, respectively. Thus, these two undoubtedly competitive currency markets have substantially more clustering than any other market we have considered. Yen-mark quotes have a range of approximately .08 and a standardized range of 1.20, roughly comparable to Nasdaq. The lower degree of clustering for yen-mark quotes is exactly what is predicted by the theory of clustering because the yen-mark exchange rate is less volatile than the dollar-mark and yen-dollar exchange rates.

We explained previously that one would expect spreads to exceed the minimum tick in markets with clustering. That is exactly what occurs. Spreads of one-eighth occur with a frequency of about 10 percent for Nasdaq stocks.[17] Our data show that on the LSE, only about 7 percent of spreads are at the customary minimum tick of one penny. We also find that the same phenomenon occurs in the FX market: during October 1994 spreads equal to the minimum possible tick never occurred for either dollar/yen or dollar/mark and occurred in only about 1.5 percent of yen/mark quo-

[17] Christie and Schultz, at 1819–20 (cited at note 1).

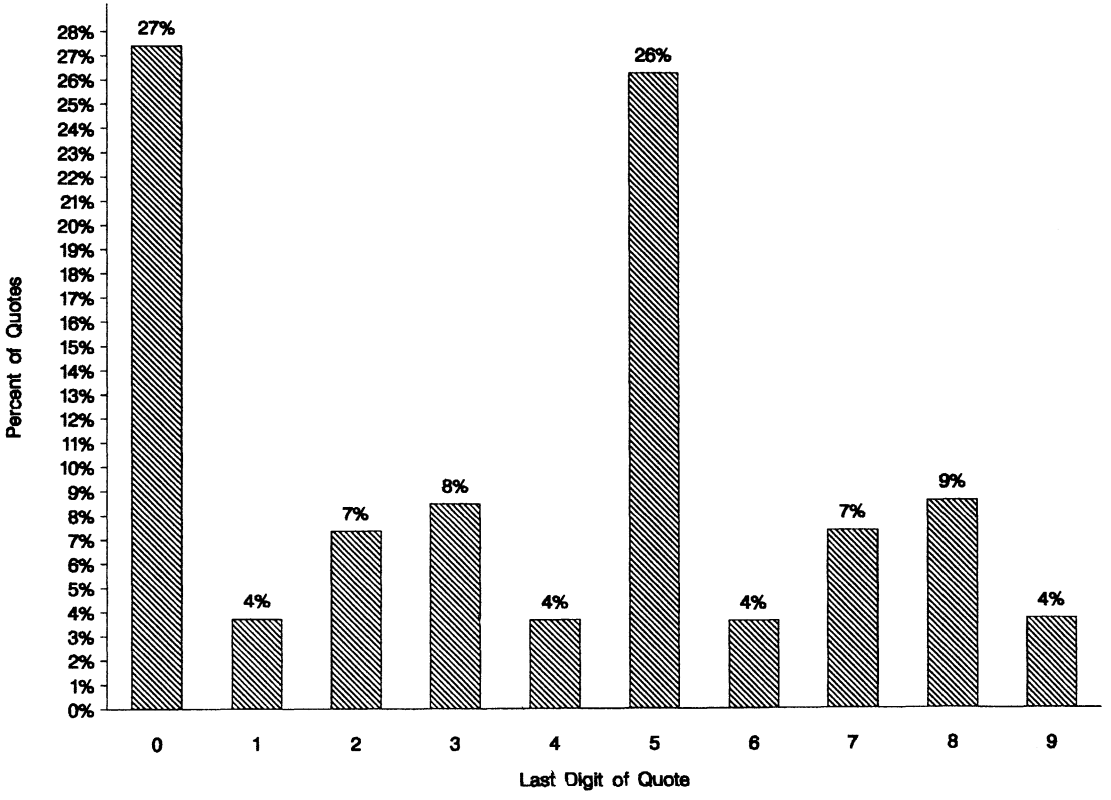

FIGURE 3.—Distribution of last digit of dealer yen/dollar quotes: international foreign exchange market, October 1992–September 1993. The figure displays the distribution of the last digit of dealer yen/dollar quotes during the period from October 1992 to September 1993. By convention, both bid and offer quotes are expressed in units of yen per dollar, to two digits. The data were obtained from Olsen and Associates (who downloaded the data from Reuters screens) and include 967,944 quotations from 342 brokers and dealers. We exclude quotes made on weekends and sequential identical quotes.

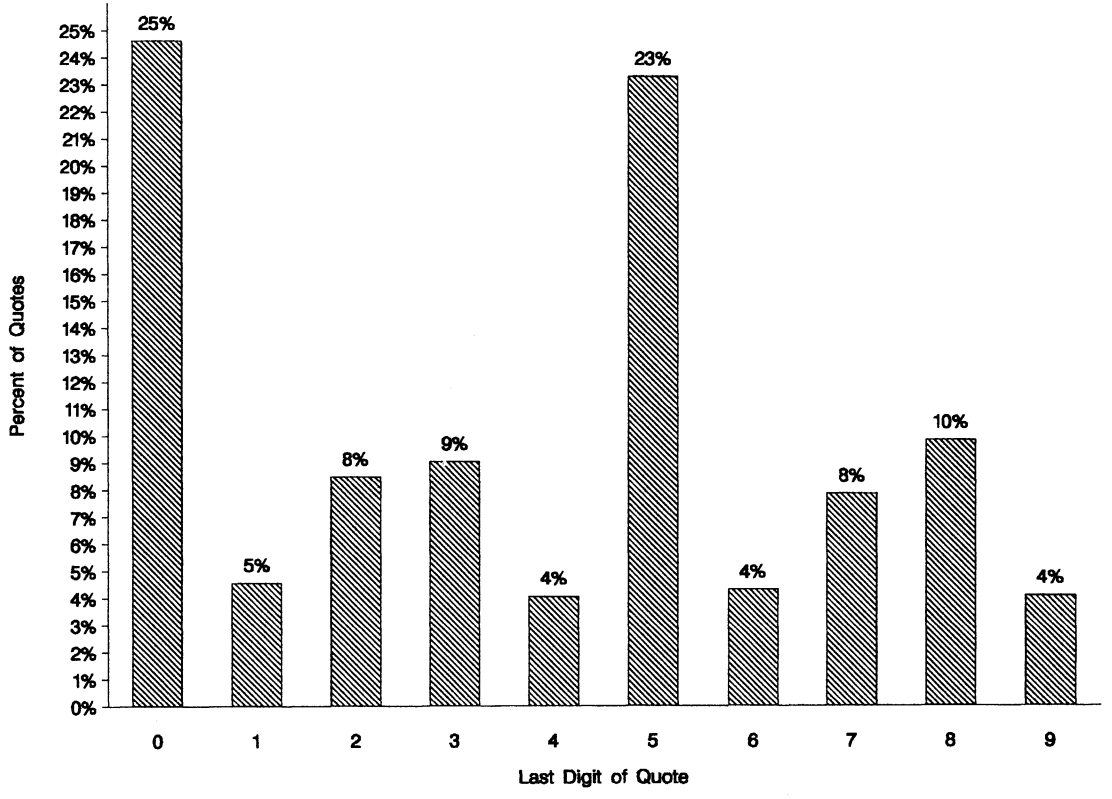

FIGURE 4.—Distribution of last digit of dealer mark/dollar quotes: international foreign exchange market, October 1992–September 1993. The figure displays the distribution of the last digit of dealer mark/dollar quotes during the period from October 1992 to September 1993. By convention, both bid and offer quotes are expressed in units of mark per dollar, to four digits. The data were obtained from Olsen and Associates (who downloaded the data from Reuters screens) and include 2,566,638 quotations from 469 brokers and dealers. We exclude quotes made on weekends and sequential identical quotes.

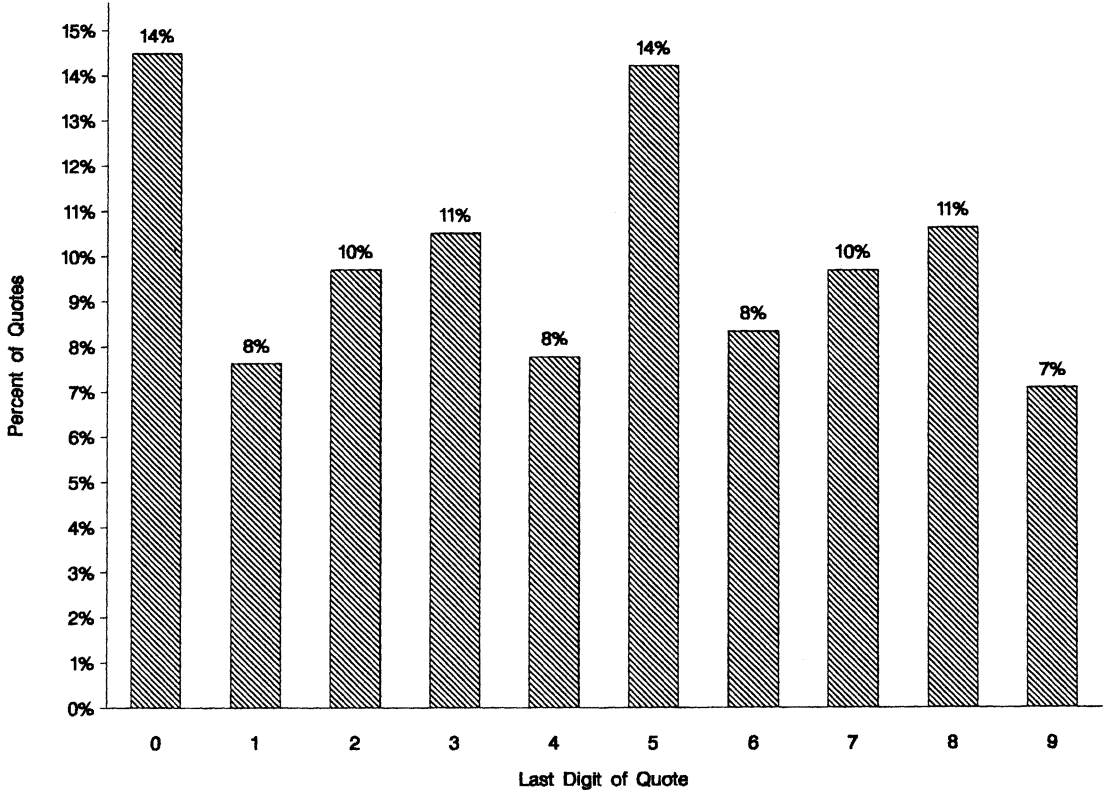

FIGURE 5.—Distribution of last digit of dealer yen/mark quotes: international foreign exchange market, October 1992–September 1993. The figure displays the distribution of the last digit of dealer yen/mark quotes during the period from October 1992 to September 1993. By convention, both bid and offer quotes are expressed in units of yen per mark, to two digits. The data were obtained from Olsen and Associates (who downloaded the data from Reuters screens) and include 287,116 quotations from 86 brokers and dealers. We exclude quotes made on weekends and sequential identical quotes.

tations.[18] In contrast, 25 percent of spreads for NYSE/AMEX stocks are at the minimum tick.[19]

4. *NYSE/AMEX.* The above data demonstrate that the degree of clustering on Nasdaq is comparable to that observed in other financial markets, and the degree of clustering on NYSE/AMEX is unusually low. As we have explained, differences in the degree of clustering can occur for many reasons. We believe that the primary reason for less clustering on NYSE/AMEX is the nature of the quote-generating process on those markets. NYSE/AMEX quotes are created by a combination of public limit orders and an exchange-designated market maker, known as the specialist, who manages the public limit order book and trades for his own account. Both investors and the specialist have strong incentives to place limit orders at odd-eighths as well as even-eighths.

Customers use all possible quote increments to obtain higher execution priority. Any investor bettering the existing quote by one-eighth is first in line when a market order arrives on the other side of the market. Investors are very different from market makers because they trade to take a position—they buy when they want to hold a security and sell when they want to reduce their holdings; market makers typically trade because they want to rapidly turn over positions at a profit. Because investors want to take a position for a relatively longer time than market makers and the extra eighth is a smaller percentage of their relatively longer holding period return, investors are more likely to prefer to trade off price for a higher probability of execution. Of course, an investor who wants to take a position immediately and with certainty will place a market order, not a limit order.

Specialists for most stocks use all possible quote increments because they are obligated by exchange rules to "make a fair and orderly market." In practice, this means limiting price changes between successive transactions to no more than one-eighth for most securities (by buying and selling for his own account when necessary). In fact, NYSE evaluates specialists by measuring "price continuity" (that is, price variation from one trade to the next), quotation spreads, and specialists' trading against the prevailing trend of the market.[20] To provide continuity, specialists may have to make quotes on odd-eighths following transactions on even-eighths.[21]

[18] In fact, for dollar-yen and dollar-mark quotations, spreads of five and 10 times the minimum tick occurred most frequently, each appearing in more than 40 percent of all quotes. For yen-mark quotations, spreads of three and five times the minimum tick occurred most frequently. We note that our data consist of dealer spreads, not inside spreads. Inside spreads cannot be wider than dealer spreads and are generally narrower.

[19] Christie and Schultz, at 1819 (cited at note 1).

[20] See, for example, *Fact Book 1992 Data,* New York Stock Exchange, April 1993, at 19.

[21] Of course, specialists do not provide continuity for nothing. Specialists are willing to provide this service because they are able to take advantage of their superior information

Unlike NYSE/AMEX, Nasdaq and other dealer markets do not have time priority rules which require that market orders are executed with the entity who first posted the current best quote. Instead, brokers are allowed to send customer orders to any market maker who either quotes the best price or agrees to match the best quoted price, a procedure known as "preferencing." Some academics have criticized Nasdaq for not having time priority rules because market makers have weaker incentives to improve the quoted spread when preferencing is allowed.[22] However, this analysis is incomplete because it fails to take into account how time priority rules would affect negotiated transactions in dealer markets. If there were an absolute time priority rule, brokers and customers would have to trade with the market maker who first posted the best price regardless of whether they preferred to trade with another market maker. The absence of absolute time priority allows customers and brokers to establish relationships with dealers pursuant to which the terms of transactions can be negotiated, allowing for more favorable executions, better service, and the moderation of adverse selection problems that occur when market makers have to deal with informed traders.[23] Time priority rules are not necessary for competition, and many competitive markets (including the futures markets and the foreign exchange market) do not have such rules.

For these reasons, more clustering should be expected in markets with dealer display systems than in markets that have price continuity requirements, public limit orders, and absolute time priority. As we have shown, there is far more clustering in many other markets than there is on NYSE/AMEX. We believe that these differences in the degree of clustering reflect differences in market structure, not differences in the degree of competition.

B. Intramarket Variation in Clustering

In addition to the intermarket variation in clustering discussed above, there is also intramarket variation in the extent of clustering. First, the extent of clustering varies among different securities traded on the same mar-

about incoming order flow by allowing public limit orders to execute when prices are unfavorable and placing limit orders inside public limit orders when prices are favorable.

[22] Godek (cited at note 4); also, see Christie and Schultz, at 1837 (cited at note 1).

[23] J. T. Green, *Trading with Nasdaq Market Makers: The Costs to Different Agents of Trading on the Nasdaq* (working paper, Indiana Univ., March 1995), finds that Nasdaq market makers provide more favorable executions to parties that are less likely to be informed (such as retail customers and institutions) as compared to parties that are likely to be informed (such as competing market makers who presumably only offer to trade at the "wrong" side of the quoted spread when they have reason to believe that prices are likely to change). Green, like us, recognizes that the quoted spread will be wider in dealer markets as compared to specialist markets when dealers are required to trade at the posted prices. Dealers will post wide spreads at which they will trade with informed investors and trade inside the spread when they receive orders from investors that are likely to be uninformed.

ket. For example, Christie and Schultz report that for 100 actively traded, large capitalization Nasdaq stocks they analyzed, 70 had fewer than 25 percent odd-eighth quotes and 30 had more. They argue that this cross-sectional variation in the extent of clustering supports the collusion hypothesis.[24] But this argument is incorrect. If clustering results from collusion among Nasdaq market makers, then one would expect to find similar clustering for all Nasdaq stocks because the firms who make markets in the stocks with substantial clustering also make markets in the other stocks. Intramarket variation in clustering is plainly inconsistent with the collusion hypothesis.

In our view, however, cross-sectional variation in the use of odd-eighth quotes is not surprising. As we have explained, the frequency of odd-eighth quotes depends on the unit of trade used by market participants. The unit of trade chosen, in turn, depends on market conditions which may vary across securities and over time. Thus, we would expect cross-sectional variation in the use of odd-eighth quotes. In fact, our data show similar cross-sectional variation for stocks traded on the London Stock Exchange: 418 of the 1,259 LSE stocks we studied had fewer than 20 percent of their quotes on the odd-digits of 1, 4, 6, and 9. As described above, we also find cross-sectional variation in the degree of clustering in the currency market.[25]

The extent of clustering also varies with the size of transactions. For example, Christie and Schultz find that the transactions prices of small orders exhibit far more clustering than the transactions prices of larger orders on Nasdaq.[26] Christie and Schultz argue that this finding also supports the collusion hypothesis. They observe that small transactions can be automatically executed using Nasdaq's Small Order Execution System (SOES) without costly negotiations, while larger trades, which are ineligible for SOES, are negotiated. They then conjecture that if the negotiation hypothesis were

[24] Christie and Schultz, at 1830–34 (cited at note 1).

[25] Christie and Schultz, id., also claim to find that "economic fundamentals" do not explain variation in the use of odd-eighths across Nasdaq stocks and suggest that this somehow also supports the collusion hypothesis. This conclusion is unfounded because they find that two of the variables they considered (the level and volatility of stock prices) do explain variation in the frequency of odd-eighth quotes. And there are many other economic factors that affect spreads and the degree of clustering that Christie and Schultz did not measure. See, for example, P. A. Laux, *The Bid-Ask Spreads of Nasdaq Stocks That Quote on Even Eighths* (working paper, Case Western Reserve Univ., Weatherhead School Mgmt, 1995). In any event, Christie and Schultz do not demonstrate that this variation in the use of odd-eighth quotes across Nasdaq securities is attributable to collusion. In fact, the Christie and Schultz model does not explain a substantial portion of the cross-sectional variation in NYSE/AMEX spreads, either. See A. Kleidon and R. Willig, *Why Do Christie and Schultz Infer Collusion from Their Data?* (working paper, Cornerstone Research and Princeton Univ., 1995).

[26] Christie and Schultz, at 1829 (cited at note 1).

correct, even-eighths would be used to reduce the costs of negotiating large trades, while small orders would be more likely to trade on odd-eighths.

This reasoning is fallacious. As explained above, the benefits of negotiation are a function of trade size; the larger the trade, the greater the value of more accurate per share pricing. However, the costs of negotiation are, for the most part, independent of trade size. Thus, one would expect *more* negotiating of larger transactions and less negotiating of smaller transactions. Small orders are less likely to be negotiated because the costs of negotiating small trades exceed the benefits. In fact, small orders executed on SOES are not negotiated at all; the automatic execution procedure is used precisely to economize on the costs of executing small trades by avoiding all negotiations. Because large transactions are negotiated, finer pricing units are more likely to be used in such trades. Thus, the finding that large orders are more likely to trade on odd-eighths is consistent with the competitive theory of clustering.

IV. Is Collusion a Plausible Explanation for Nasdaq Clustering?

Proponents of the collusion hypothesis assert that clustering occurs because market makers agree to post quotes only on even-eighths. They argue that by doing so, dealers hope to widen spreads artificially, thereby raising profits and increasing the trading costs of investors. In their view, Nasdaq's electronic trading system aids collusion because dealers' quotes are easily observed by other dealers, allowing any cheating on the cartel to be easily detected and punished.[27] In this section, we evaluate the plausibility of this alleged scheme. We conclude that the alleged scheme is highly implausible to say the least, and, in light of the better explanations for clustering provided above, we reject the hypothesis that Nasdaq clustering occurs because of collusion.

There is no trading floor on Nasdaq. Instead, Nasdaq uses computers and telecommunications networks to trade securities. Each company that lists its shares on Nasdaq has a number of competing securities firms making a market in its stock—a minimum of two market makers is required for listing. Each market maker must enter and maintain two-sided quotations on Nasdaq. The quotations are transmitted electronically to specially designed terminals in brokerage firms throughout the country. All subscribers are

[27] See, for example, Christie and Schultz, at 1834–1836 (cited at note 1). Christie, in fact, has suggested that investors have been "robbed" because of Nasdaq's "anticompetitive" spreads. See Warren Getler and William Power, *Small Stock Focus: Nasdaq Critic Vows He Isn't Taking Sides,* Wall St J (November 21, 1994), at C1. The existing investor lawsuits also presuppose that higher spreads mean higher trading costs.

provided with inside bid and ask quotes and subscribers with Level II and Level III terminals can see the quotes of all market makers in a stock.[28] When an investor places an order to buy or sell a Nasdaq security, his or her broker will route the order to a market-making firm (or to the firm's trading room if it is a market maker in the security) for execution.

This market structure makes collusion implausible for several reasons. First, the number of actual competitors on Nasdaq is so large that collusion is unlikely. Generally, the more sellers in a market, the more difficult it is for any seller to maintain prices above cost. When there are many sellers, each seller has an incentive to cheat on any collusive agreement. In each year since 1983 more than 400 firms have operated as market makers on Nasdaq.[29] Of course, fewer firms make markets in any particular stock. However, most stocks traded on Nasdaq have many market makers. Between 1989 and 1993 there have been more than 10 market makers per security, on average.[30]

To verify that concentration on Nasdaq is at a level that would make successful collusion extremely unlikely, we calculated the Herfindahl-Hirshman Index (HHI). The HHI is a well-known and widely used measure of concentration that is calculated by summing the squared values of the market shares of all market participants. The statistic can take on values ranging from 0 to 10,000. Under the current *Horizontal Merger Guidelines,* used by the Department of Justice and the Federal Trade Commission to review proposed mergers, markets with HHIs below 1,000 are regarded as unconcentrated. We calculated the HHI for all Nasdaq/NMS securities in 1991 to be 346 and in 1994 to be 277. These low HHIs indicate an unconcentrated market where anticompetitive activity is unlikely to occur.

Ease of entry is another reason that collusion among Nasdaq market makers is unlikely. Any firm that can demonstrate compliance with the net capital and other financial responsibility provisions of the governing rules and regulations can become a Nasdaq market maker. Similarly, because any firm registered as a market maker and in compliance with the regulations can elect to make markets in any Nasdaq security, the number of potential competitors for any stock is extremely large. Easy entry makes collusion unlikely because if a collusive agreement did cause market makers' profits

[28] Level I service provides subscribers with inside bid and ask quotes. Level II terminals allow broker-dealers to see the quotes of all market makers in any stock. Level III service is intended expressly for market makers; it provides the same information as Level II service but also allows market makers to enter, change, or update quotes.

[29] *1994 Nasdaq Fact Book and Company Directory,* at 35.

[30] Id at 14. We determined that for the Nasdaq stocks Christie and Schultz analyzed, there was an average of 24 market makers per security.

to increase above competitive levels, entry would occur until the additional competition caused profits to return to competitive levels.

Proponents of the collusion hypothesis recognize that the number of actual and potential competitors on Nasdaq is large. Nevertheless, they argue that Nasdaq facilitates collusion with respect to quotes because its screen-based trading system allows market participants to quickly detect and identify any market maker who uses odd-eighths, thereby facilitating agreements to avoid odd-eighths.[31] This argument is incomplete for three reasons.

First, it does not explain why market makers would agree to avoid odd-eighths. If market makers wanted to raise the inside spread, the most direct way of doing so would be to agree on the size of the spread, not on the units used for quotations. In fact, if market makers could agree, it would be possible to have large inside spreads without *any* clustering. Proponents of the collusion hypothesis assert that an agreement not to quote odd-eighths is a simpler mechanism to effect an increase in average spreads, but this is not obvious. Consider how average spreads would behave if NASD changed the minimum tick from one-eighth to one-quarter. Securities that would otherwise have a three-eighths spread might then trade with spreads of one-quarter or one-half, or some combination of the two.[32] There is no reason to believe that the average spread for such securities would rise. Only securities that would otherwise have a one-eighth spread would necessarily have higher spreads in the absence of odd-eighth quotes. The imprecise relation between the units in which quotes are made and the average size of spreads calls into question the alleged anticompetitive rationale for a collusive agreement to restrict the use of odd-eighth quotes.

The collusion hypothesis also ignores the possibilities for cheating created by alternative systems available to Nasdaq market makers that allow them to post anonymous quotes. One of these systems is Nasdaq's SelectNet Service, which allows Nasdaq order-entry subscribers and Nasdaq market makers to place (and accept) anonymous offers to buy or sell any amount of any security at any price. Another alternative system is Reuters' Instinet Real-Time Trading Service, an electronic system that allows subscribers to enter anonymous bids and offers for any NYSE, AMEX, or

[31] Critics of Nasdaq also point to anecdotal evidence of complaints made by other market makers to market makers who post quotes that narrow the inside spread. We are unaware of the veracity or frequency of such anecdotes but would not be surprised to find market participants in any industry that were upset about the activities of aggressive competitors. In any event, there is a great deal of intertemporal variation in Nasdaq spreads, and, as we demonstrate below, sudden, dramatic and permanent declines in inside spreads are not uncommon, notwithstanding these anecdotes.

[32] Christie and Schultz (cited at note 1) find that 45 percent of Nasdaq securities they studied have spreads of $\$3/8$ or more.

Nasdaq security.[33] Because quotes on these systems are anonymous, market makers might be able to circumvent any agreement to avoid using odd-eighth quotes by posting such quotes on these alternative systems.[34]

Finally, the collusion hypothesis ignores the ability of market makers to compete in other areas. A market-making firm's profit is determined by the prices at which it trades as well as the costs of trading, not the prices it quotes. Therefore, profitable collusion would require an agreement on transactions prices, not an agreement on quotes. Such an agreement would be unlikely to succeed because, while each market maker's quotes are displayed on Nasdaq screens and easily observed, a market maker's transactions are not. Every market maker is able to execute any trade at prices that are better than the existing quotes. Thus, an agreement on quotes would not prevent a market maker from "cheating" on any proposed cartel by executing orders of any size at more favorable prices.[35] Such cheating would compete away any profits from an agreement to quote wider spreads, making it unlikely that any agreement would be made in the first place.[36]

The possibility for cheating would be enhanced when customers placed large orders. For these orders, the quoted spread does not bound the cost of trading because dealers are not obligated to trade larger than posted quantities at the spread and market makers may change their quotations in response to large orders. In fact, for large orders, it is possible to obtain worse executions when spreads are narrow and more favorable executions when spreads are wide.[37] Obviously, market makers could cheat on any collusive

[33] Proprietary trading systems such as Reuters' Instinet have reportedly captured 13 percent of the volume in Nasdaq stocks. See U.S. Securities and Exchange Commission, *Market 2000: An Examination of Current Equity Market Developments* (1994), at 10.

[34] When SelectNet orders are filled, the transaction is publicly reported and the parties to the transaction learn each others' identity, but this information is not disseminated publicly. This would make it difficult for any cartel to punish violators.

[35] About 25 percent of Nasdaq trades, amounting to 40 percent of volume, are executed inside the spread. In fact, Christie and Schultz find trades on odd-eighths even for stocks that are not usually quoted in odd-eighths. See Christie and Schultz, at 1830 (cited at note 1). In our analysis, trading inside the quoted spreads on Nasdaq results from the informational role of quotes and the ability of market makers to distinguish informed from uninformed traders. Also, see Green (cited at note 23).

[36] The bid-offer spread only determines a market maker's profit in the special case where the market maker is able to "cross" trades, that is, buy at the bid and sell at the offer simultaneously. In the more general case, even when the market maker trades at his quoted prices, the market maker may earn more or less than the spread quoted when the first part of a round-trip transaction occurs because prices may change before the other side of the trade occurs. For a fuller discussion of these points, see Sanford Grossman and Merton Miller, *Liquidity and Market Structure,* 43 J Fin 617, 628 (1988).

[37] To illustrate, suppose security ABC trades on NYSE and a customer places a market order to buy 10,000 shares. Suppose further that when the order arrives, the specialist's book contains offers to sell 1,000 shares at $8\frac{1}{8}$, 1,000 shares at $8\frac{1}{4}$, 2,000 shares at $8\frac{3}{8}$, and 6,000 shares at $8\frac{1}{2}$. Further suppose that the current bid is $8, making the spread $\frac{1}{8}$. Under

agreement by executing large orders at favorable prices without regard to the spread.[38]

V. Variation in Spreads and Clustering over Time

There was a dramatic narrowing of spreads and increase in the appearance of odd-eighth quotes for four securities on or about May 26, 1994, when the collusion hypothesis was first reported in newspapers: the average quoted spread between bid and offer quotes for Amgen, Inc., Apple Computer, Inc., Cisco Systems, and Microsoft Corp. each declined by approximately 50 percent, and the frequency of odd-eighth quotes for each of these securities increased from approximately 3 percent to about 40 percent.[39] Both economists and other commentators have claimed that the decline in spreads and the increase in the frequency of odd-eighth quotes demonstrate the collapse of an implicit pricing agreement.[40]

The claim that an implicit pricing agreement collapsed on May 26, 1994, has two testable implications. First, if the claim were correct, then other Nasdaq securities that were not quoted in odd-eighth quotes prior to May 26 should have had systematic and similar decreases in spreads and increases in the frequency of odd-eighth quotes after May 26. Second, we

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these circumstances, unless the specialist intervenes or additional offers arrive, the market order would lift all of these offers, and the average cost would be $8.41 per share. At the same time, there might be another security trading on Nasdaq, say security XYZ, that has price and market capitalization similar to security ABC ("comparable" in the sense of Christie and Schultz). Suppose XYZ has a current bid of $8 and a current ask of $8¼, making the spread $¼. Under these circumstances, one or more market makers might sell the customer all 10,000 shares at the current ask of $8¼. In that case, his average cost would be less than the cost of purchasing security ABC on the NYSE even though ABC has tighter spreads.

[38] This does not mean that competition is limited to large orders. While orders for less than the posted quantities can be automatically executed at the quoted spread, market makers can also execute small orders at more favorable prices. Even if small investors do not negotiate directly with market makers to obtain the best prices, their brokerage firms may do so on their behalf. Brokers also vertically integrate by becoming market makers. This gives them the ability to provide their customers with favorable executions as well as other services such as discounted commissions and research and ancillary services through "soft dollar" arrangements. See, for example, M. E. Blume, *Soft Dollars and the Brokerage Industry,* 49 Fin Anal J 36 (1993). Competition in these areas could compete away any profits created by a hypothetical agreement to quote higher spreads, making it unlikely that such an agreement would ever be made.

[39] Christie, Harris, and Schultz, at 1841, 1852 (cited at note 3). The authors also report a much less dramatic decline in average daily spreads and a much less dramatic increase in odd-eighth quote frequency for Intel Corp. beginning on June 10. We demonstrate below that the pattern of average daily spreads and odd-eighth quote frequency for Intel and other stocks is inconsistent with collusion.

[40] Id. One prominent plaintiffs' attorney has called these events the "most damning piece of evidence" of collusion on Nasdaq.

should not expect to find decreases in spreads and increases in the frequency of odd-eighth quotes for other securities at other times.

To examine these implications, we studied quotes and spreads of the Nasdaq securities analyzed by Christie and Schultz other than the four securities.[41] Figure 6 reports the quote fractions for these securities before and after May 26. These data show essentially no difference in the degree of clustering before and after May 26.[42] This finding is inconsistent with the conspiracy claim because the disproportionate use of even-eighths continued after newspaper reports regarding the collusion hypothesis appeared.

We have also studied the quotation patterns for these securities over time. Apart from the four securities, 56 of the other securities analyzed by Christie and Schultz were not frequently quoted in odd-eighths in January 1993 (that is, the frequency of odd-eighth quotes was less than 25 percent). Of these, 20 had significant increases in the use of odd-eighth quotes and declines in spreads at some time during the period from January 1993 to December 1994, but not near May 26, 1994. Table 1 illustrates these switches by reporting for each of the 20 securities the average daily spread and the odd-eighth quote frequency prior to and after the switch date.[43]

This pattern is not restricted to these stocks. We also analyzed the 500 largest capitalization Nasdaq stocks as of year end 1993 and found dozens of other securities that had sudden dramatic decreases in average daily spreads during the period from January 1993 to December 1994. However, none of these dramatic changes occurred on or about May 26, 1994. These data support our conclusion that such sudden declines in spreads are not unusual and were not caused by the collapse of a collusive pricing agreement.[44]

The decline in spreads for these securities during this period appears to be part of a more general decline in spreads. Figure 7 reports the average daily spread for the 500 largest capitalization Nasdaq securities and NYSE/AMEX securities during the same period. The figure shows that spreads for both Nasdaq and NYSE/AMEX securities generally declined during this

[41] Of the 100 stocks analyzed by Christie and Schultz other than the four stocks, only 80 traded on Nasdaq and were quoted in eighths as of May 26, 1994.

[42] None of these securities had changes in spreads or odd-eighth quote frequency on or about May 26, 1994, comparable to the dramatic changes that Christie, Harris, and Schultz report for the five securities they analyzed.

[43] The table also reports data for one stock, Heartland Express, that had a dramatic increase in the frequency of odd-quarter quotations, not odd-eighth quotations, on December 16, 1993. This pattern is inconsistent with the conspiracy claim, not only because the switch did not occur on May 26, 1994, but also because the conspiracy claim cannot explain why market makers stopped avoiding the use of odd-quarters but continued avoiding odd-eighths.

[44] Again, these data are available from the authors upon request.

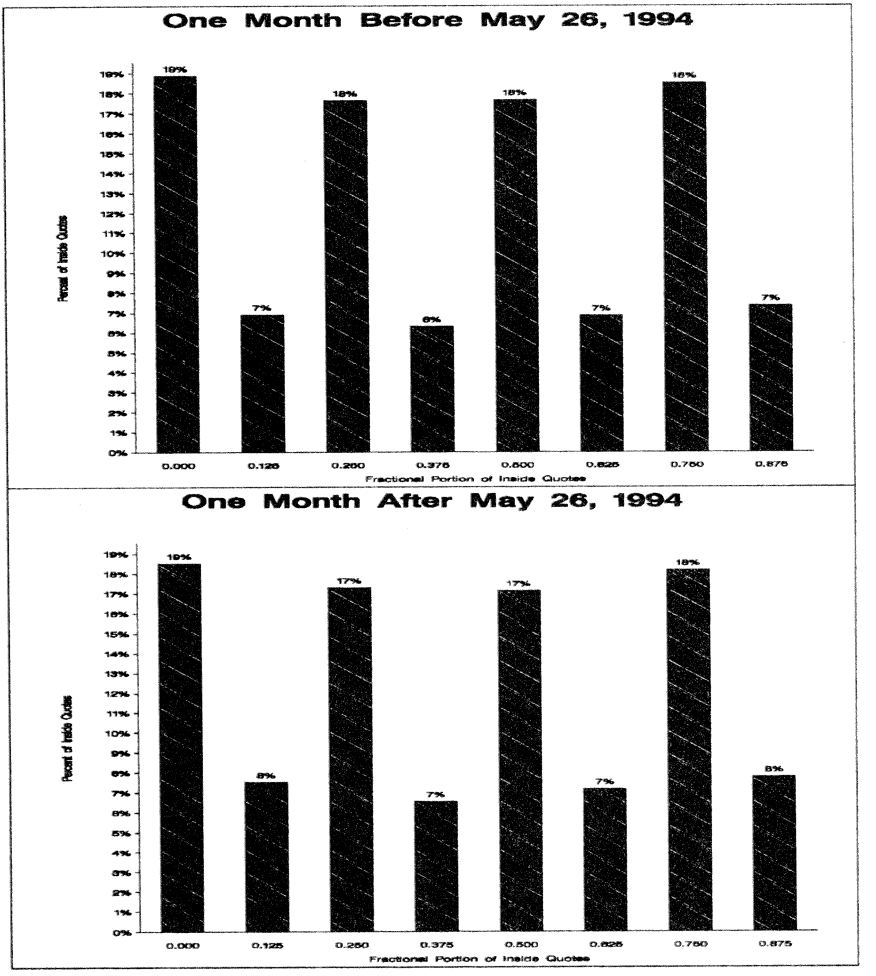

FIGURE 6.—Distribution of inside bid and offer quotes: Nasdaq stocks analyzed in Christie and Schultz (1994) but not analyzed in Christie, Harris, and Schultz (1994). These figures display data for the 80 stocks analyzed in Christie and Schultz but not in Christie, Harris, and Schultz that traded on Nasdaq and were quoted in eighths as of May 26, 1994. The top panel reports the distribution of the fractional portion of quotes in the 1 month prior to May 26, 1994 (the day of newspaper reports regarding Christie and Schultz). The bottom panel reports the distribution for the 1 month after May 26, 1994. Quote data were obtained from the Trade and Quote (TAQ) Database.

TABLE 1

AVERAGE DAILY INSIDE SPREAD AND ODD-EIGHTH QUOTATION FREQUENCY CHRISTIE AND SCHULTZ STOCKS WITH SPREAD AND QUOTE FREQUENCY CHANGES NOT OCCURRING NEAR MAY 26, 1994

Name	Switch Date	Pre-Switch Average Spread	Post-Switch Average Spread	Pre-Switch Odd-Eighth (%)	Post-Switch Odd-Eighth (%)
Aldus Corp.	March 4, 1994	.479	.259	1.40	45.7
Biomet, Inc.	June 8, 1993	.327	.175	1.68	51.3
Borland Intl., Inc.	October 4, 1993	.340	.203	1.59	50.4
Centocor, Inc.	January 18, 1993	.342	.193	.69	49.9
Costco Wholesale Corp.	August 24, 1993	.309	.165	4.18	49.5
El Paso Electric Co.	May 4, 1993	.134	.098	66.3	69.0
Electronic Arts, Inc.	November 8, 1994	.346	.181	1.53	48.7
Emcon	February 19, 1993	.581	.409	.12	21.0
Healthdyne, Inc.	May 20, 1993	.398	.242	6.79	49.4
Healthinfusion, Inc.	August 24, 1993	.393	.269	8.44	51.3
Heartland Express*	December 16, 1993	1.421	.797	39.5	60.4
Intel Corp.	October 24, 1994	.275	.142	4.86	51.0
McCormick Co. Non Vtg	August 2, 1994	.402	.205	1.49	50.1
McCaw Cellular Commun., Inc. CL-A	April 8, 1994	.351	.198	1.91	49.4
Medco Containment SVCS, Inc.	July 28, 1993	.342	.171	.58	50.5
Novell, Inc.	August 30, 1993	.292	.155	1.53	50.6
Price/Costco, Inc.	August 24, 1993	.401	.181	1.24	51.2
Radiation Systems, Inc.	March 4, 1994	.573	.285	3.37	44.1
Rainbow Technologies, Inc.	July 18, 1994	.531	.289	3.28	50.1
Stryker Corp.	October 27, 1994	.410	.255	.69	41.7
Synergen, Inc.	February 22, 1993	.484	.211	.68	50.9

NOTE.—The table displays data for the period January 1993 to December 1994 for Nasdaq stocks analyzed by Christie and Schultz which experienced significant spread declines and odd-eighth quotation frequency increases on dates more than a month before or after May 26, 1994. Quote data were obtained from the TAQ database.

* Heartland Express percentages are odd-quarters rather than odd-eighths.

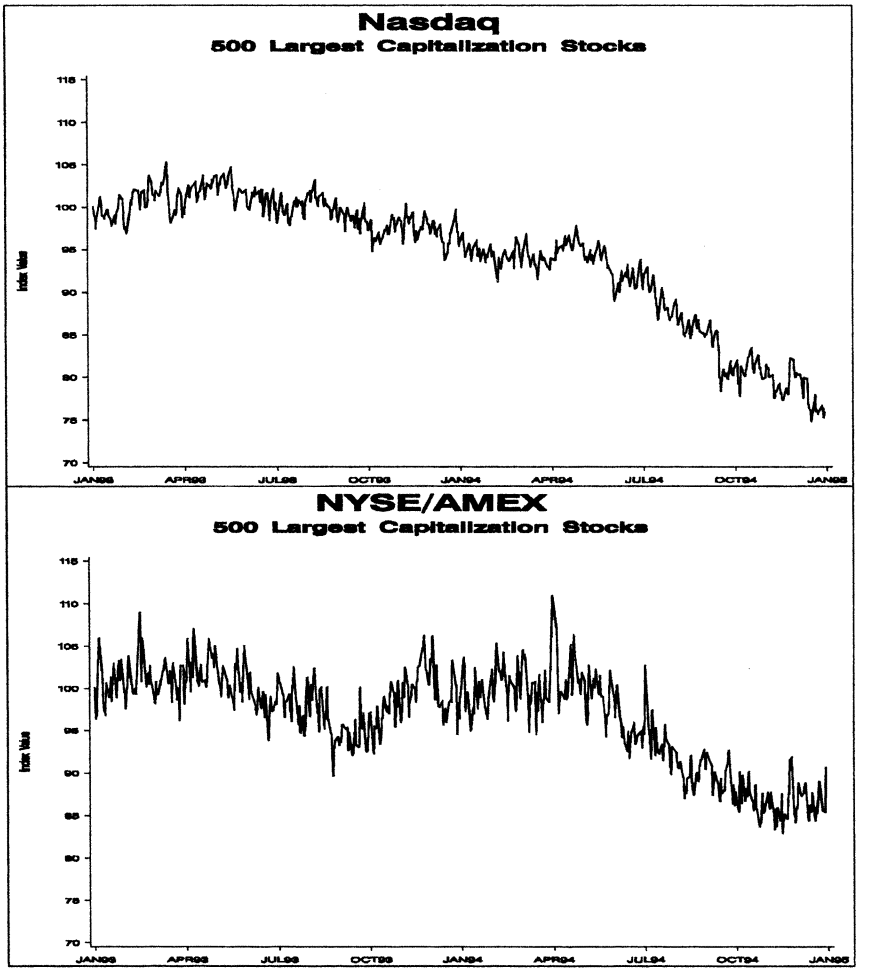

FIGURE 7.—Average daily inside spread, January 1993–December 1994 (January 4, 1993 = 100). This figure displays an indexed value of the average daily inside spread for the 500 largest capitalization Nasdaq and NYSE/AMEX stocks as of year end 1993. The indexed value for each panel is set to 100 on January 4, 1993, and displays changes in the average daily inside spread thereafter. As a screen for erroneous data, we eliminated all spreads greater than $10 and any average inside spread that exceeded the closing spread by more than a factor of 20. Market capitalization data were obtained from the Center for Research in Security Prices (CRSP), University of Chicago. Quote data were obtained from the TAQ Database.

period, particularly since April 1994. Figure 8 demonstrates that this decline in spreads has been accompanied by a general increase in the use of odd-eighth quotes for Nasdaq securities. Of course, the decline in spreads does not mean that there has been a significant decline in the cost or profitability of market making. As Figure 9 demonstrates, the average daily percentage spread has no consistent pattern during this period. This implies that the average price of securities also declined during this period, largely offsetting the decline in average spreads.

Thus, we conclude that the sudden change in spreads and odd-eighth quote frequency for four large actively traded securities in a single day is not attributable to the collapse of an implicit pricing agreement. We believe that the threat of regulatory action provides a better explanation for this unusual phenomenon. On May 24, 1994, Richard Ketchum, the president of NASD, reportedly told a group representing more than 100 dealers to narrow their spreads in order to be competitive with other stock markets.[45] We would not expect market makers to quote narrower spreads if it were completely uneconomic to do so. But, as we have demonstrated above, spreads were generally declining at this time. The NASD's urging may have prompted some Nasdaq market makers to review their spreads for some or all of these four securities, which may have been likely candidates for narrower spreads in any event.[46]

VI. Competition and the Costs of Transactions

The belief that Nasdaq clustering is evidence of a defective market structure stems from the concern that clustering results in higher spreads and that higher spreads, in turn, beget higher transactions costs. However, as we have already explained, there is no necessary relationship between the degree of clustering and the average size of spreads. In this section, we address the additional concern that higher spreads result in higher transactions costs.

Nasdaq spreads are higher, on average, than NYSE spreads. Some have claimed that because Nasdaq spreads are higher than NYSE/AMEX

[45] See *NASD Threatens Possible Regulation of Spreads If Traders Don't Conform Voluntarily,* Sec Week (May 30, 1994), at 1.

[46] There is some evidence that economic factors explain the decline in spreads for the four securities. One of the four securities, Microsoft Corp., had a two for one stock split on May 23, 1994, four days before the decline in spreads they observed. The decline in Microsoft's spread (in dollar terms) that occurred on May 27 caused its spread in percentage terms to be approximately the same as it had been prior to the split. We have also found that at various dates prior to May 26, the percentage spreads of Apple, Amgen, and Cisco Systems each were approximately the same as the percentage spreads thereafter.

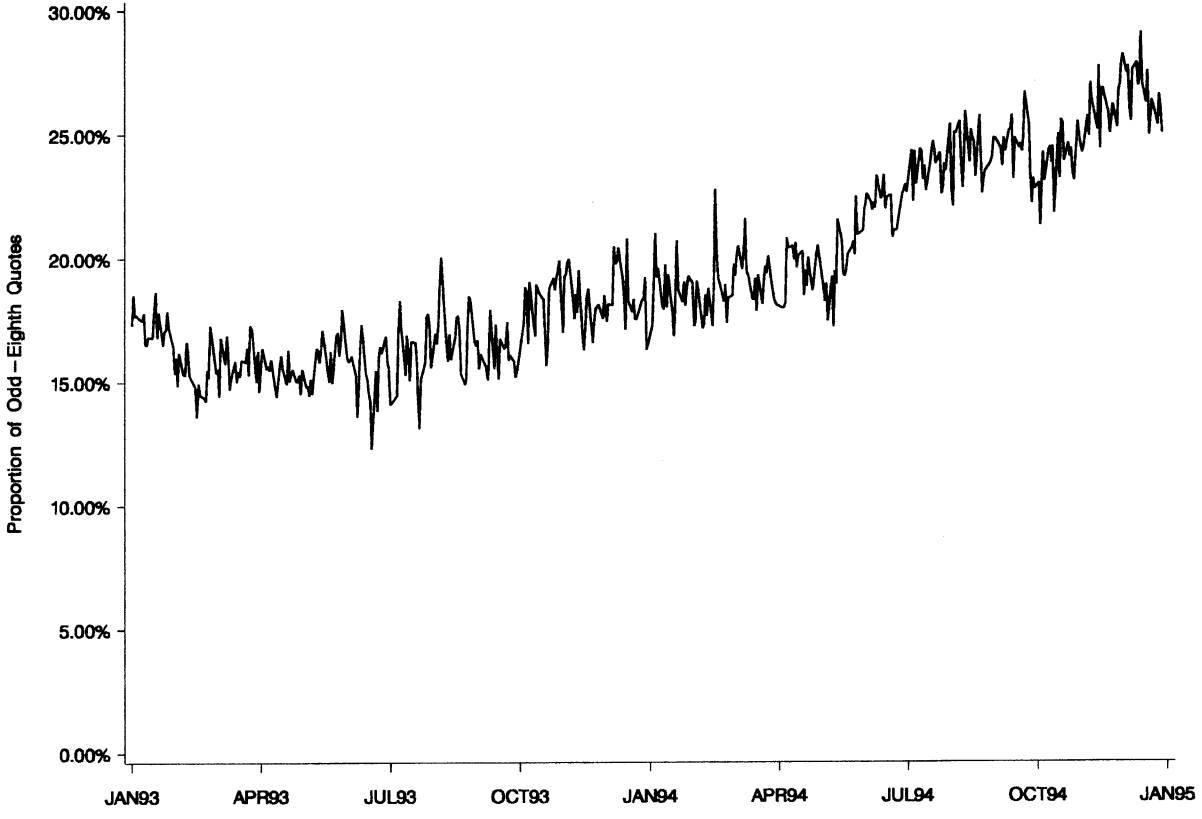

FIGURE 8.—Proportion of odd-eighth quotes: 500 largest stocks traded on Nasdaq, January 1993–December 1994. This figure displays the daily proportion of quotes on odd-eighths for the 500 largest capitalization Nasdaq stocks as of year end 1993. Days when a stock has quotes on finer increments than eighths have been eliminated from the analysis. Market capitalization data were obtained from the Center for Research in Security Prices (CRSP). Quote data were obtained from the TAQ Database.

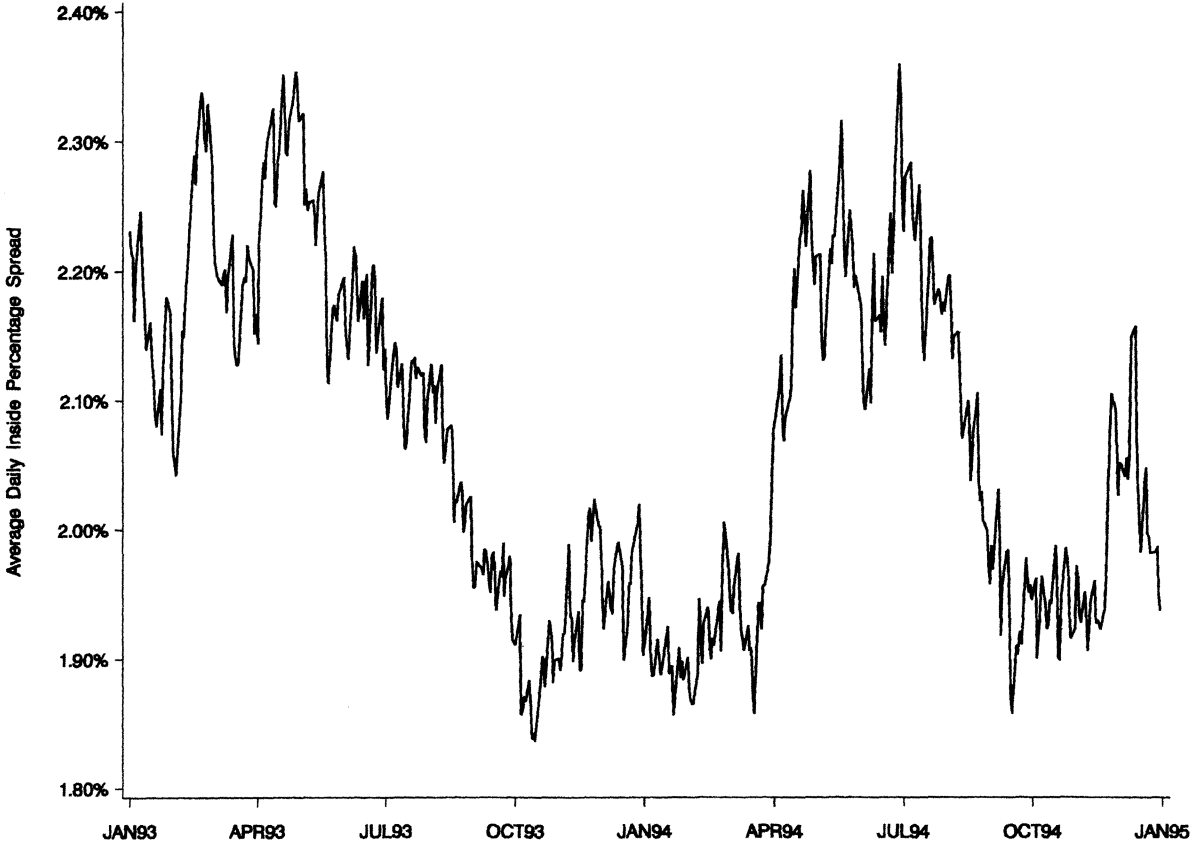

FIGURE 9.—Average daily inside percentage spread of 500 largest stocks traded on Nasdaq, January 1993–December 1994. This figure displays the average daily inside percentage spread for the 500 largest capitalization Nasdaq as of year end 1993. The percentage spread is calculated by dividing the inside spread by the average of the inside bid and inside ask. As a screen for erroneous data, we eliminated all spreads greater than $10 and any average inside spread that exceeded the closing spread by more than a factor of 20. Market capitalization data were obtained from the Center for Research in Security Prices (CRSP). Quote data were obtained from the TAQ Database.

spreads, on average, Nasdaq investors have higher average trading costs.[47] However, the cost of trading cannot be determined by examining spreads alone. The value of the brokerage services investors receive depends on many factors, including the quality of executions, the amount of commissions, and the availability of free research and other services.[48]

For many trades, the most important determinant of transactions costs is market liquidity (or market depth)—the extent to which an investor can trade large volumes without affecting price. Unfortunately, market liquidity is not easily measured. To measure liquidity for any particular security, one would like to observe the price effects of trades of various sizes for immediate execution made by uninformed traders. Actual trading data are unsuited for this task for many reasons. First, many characteristics of trades are unobservable. For example, one typically does not know whether a trade was initiated by a liquidity trader or an informed trader, whether the trade was buyer-initiated or seller-initiated, and whether the trade was made immediately or after a search for willing counterparties. Moreover, actual trades are made by persons engaged in optimizing behavior who are trying to minimize the costs of their trades rather than as part of a laboratory experiment for researchers attempting to measure liquidity.

Comparing the liquidity of different stock markets is more difficult. First, for the reasons described above, there is the problem of measuring liquidity for securities traded in any particular market. In addition, to compare measurements in different markets, one must take into account any systematic differences in the nature of the securities that trade in the different markets. While some relevant characteristics of different securities can be observed and measured, others cannot. Moreover, any comparison may be contaminated by a selection bias because firms presumably choose to list in the market that maximizes the price at which their securities trade by minimizing transactions costs.

For these reasons, studies that attempt to measure market depth directly must be interpreted with great caution. In trying to compare depth on different markets, three basic methodologies have been used. Some studies have tried to measure depth by studying the relationship between reported volume and price for trades of various sizes.[49] Others have tried to measure

[47] Christie and Schultz, at 1836 (cited at note 1). Also, see R. D. Huang and H. R. Stoll, *Dealer versus Auction Markets: A Paired Comparison of Execution Costs on Nasdaq and the NYSE* (Working Paper 95-16, Vanderbilt Univ., Owen Grad School Mgmt, 1995).

[48] Differences in commissions alone can be substantial. For example, institutions and large individual clients pay commissions on NYSE/AMEX trades but do not pay commissions on Nasdaq trades. For such investors, commissions on NYSE/AMEX stocks average more than five cents per share. See W. H. Wagner and M. Edwards, *Best Execution,* 49 Fin Anal J 65 (1993).

[49] See, for example, S. K. Cooper, J. C. Groth, and W. E. Avera, *Liquidity, Exchange Listing, and Common Stock Performance,* 37 J Econ Bus 19 (1985); Terry Marsh and Kevin

depth by studying transactions of particular investors.[50] Still other studies have tried to infer market depth from comparisons of asset returns (reasoning, as we do below, that higher returns are necessary to compensate for reduced liquidity).[51] The results of these studies have been mixed: some studies have found that auction markets such as NYSE/AMEX provide uniformly greater liquidity, other studies have found the reverse, and still other studies have found that dealer markets such as Nasdaq provide generally greater liquidity for certain securities (typically smaller capitalization issues) but less liquidity for others.

Thus, existing attempts to measure and compare transactions costs in different markets have had ambiguous results. However, some inferences about relative transactions costs can be made by observing the behavior of issuers and investors. Both issuers and investors will alter their behavior when market rules affect liquidity and other transactions costs. All else equal, securities with higher expected transactions costs will sell at lower prices. The lower price is necessary to equilibrate investors' expected returns from holding assets with higher transactions costs with their returns from holding otherwise similar assets with lower transactions costs. Not surprisingly, academic studies have found that assets with higher transactions costs provide investors with greater gross returns to compensate them for the greater costs.[52] Because investors will take into account expected transactions costs in determining whether to invest, an issuer who chooses to list in a market that has higher transactions costs would expect to receive a lower offer price when the firm sells shares to the public.[53]

If transactions costs were higher on Nasdaq, then firms who meet NYSE and AMEX listing requirements would list on one of these exchanges instead of Nasdaq in order to maximize the price of their securities, thereby

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Rock, *Exchange Listing and Liquidity: A Comparison of the American Stock Exchange with the NASDAQ National Market System,* American Stock Exchange (1986); Anand Vijh, *Liquidity of the CBOE Equity Options,* 45 J Fin 1157 (1990); and Robert Neal, *A Comparison of Transaction Costs between Competitive Market Maker and Specialist Market Structures,* 65 J Bus 317 (1992).

[50] See Louis K. C. Chan and Josef Lakonishok, *A Cross-Market Comparison of Institutional Trading Costs* (unpublished manuscript, Univ. Illinois, November 1993).

[51] See, for example, Marc Reinganum, *Market Microstructure and Asset Pricing: An Empirical Investigation of NYSE and NASDAQ Securities,* 28 J Fin Econ 127 (1990); and Tim Loughran, *NYSE vs NASDAQ Returns: Market Microstructure or the Poor Performance of Initial Public Offerings?* 33 J Fin Econ 241 (1993).

[52] See, for example, Y. Amihud and H. Mendelson, *Asset Pricing and the Bid-Ask Spread,* 17 J Fin Econ 223 (1986).

[53] Of course, all else equal, issuers would be less willing to pay listing fees for exchanges that have higher transactions costs and investors would be less willing to trade securities on exchanges that have higher transactions costs. The resulting reduction in listing fees and trading commissions provides exchanges with incentives to adopt rules that reduce such costs.

TABLE 2

SECONDARY OFFERINGS ON NASDAQ, NYSE, AND AMEX, 1991–93

	Issues with Secondary Offerings	Average Number of Issues	Percent of Issues with Offerings
Nasdaq national market	712	3,026	23.5
NYSE	542	2,670	20.3
AMEX	132	1,003	13.2

SOURCES.—Securities Data Company, New York; University of Chicago Graduate School of Business, Chicago; Center for Research in Security Prices, Chicago.

benefiting the owners of these firms. However, most of the companies listed on the Nasdaq National Market System (Nasdaq/NMS) meet AMEX listing requirements, and several hundred Nasdaq/NMS firms, including many well-known and successful companies such as Apple Computer, Inc., Intel Corporation, Microsoft, and MCI Communications Corporation meet NYSE listing requirements.[54] Moreover, Nasdaq has been far more successful in attracting new listings than either NYSE or AMEX. In 1983, 682 issues were listed on Nasdaq/NMS, 948 issues were listed on AMEX, and 2,307 issues were listed on the NYSE. However, by 1993 the number of issues listed on Nasdaq/NMS had increased more than 500 percent, to 3,436. During this same period the number of issues listed on AMEX and NYSE increased by only 6 percent (to 1,010) and 27 percent (to 2,927), respectively. In addition, over-the-counter trading of 19c-3 stocks, which trade on both NYSE and Nasdaq, has increased markedly since 1988.[55] This success is also inconsistent with the claim that transactions costs are higher on Nasdaq.

If transactions costs were higher on Nasdaq, then firms currently listed on Nasdaq that wanted to sell additional securities to the public would have especially strong incentives to switch listings in order to maximize the proceeds from securities offerings; accordingly, we would not expect to find many Nasdaq firms with secondary stock offerings. For this reason, we studied secondary stock offerings of AMEX and Nasdaq firms during the period from 1991 to 1993. Our findings are presented in Table 2. The data

[54] See, for example, John T. Wall, *The Competitive Environment of the Securities Market,* in Ykov Amihud, Thomas S. Ho, and Robert A. Schwartz, eds, *Market Making and the Changing Structure of the Securities Industry,* at 132 (1985); and A. R. Cowan, R. B. Carter, F. H. Dark, and A. K. Singh, *Explaining the NYSE Listing Choices of NASDAQ Firms,* 21 Fin Man 73 (1992).

[55] J. L. Davis and L. E. Lightfoot, *Fragmentation vs. Consolidation of Securities Trading: Evidence from the Operation of Rule 19c-3,* Office of Economic Analysis, Securities and Exchange Commission, Washington, D.C. (1995).

show that there were more secondary issues of Nasdaq listed securities than secondary issues of NYSE listed securities and AMEX listed securities combined. Moreover, the likelihood of having a secondary offering was greater for Nasdaq listed securities than for either NYSE or AMEX listed securities. These findings are also inconsistent with the claim of higher transactions costs on Nasdaq.

Of course, some firms that were listed on Nasdaq have switched to NYSE/AMEX. Presumably firms that switch listings do so because they expect to benefit from the switch. If these expectations are rational, one would expect these firms to benefit from switching, on average. Of course, a finding that switching firms benefited from switching would not mean that nonswitching firms would benefit from switching; nonswitchers are different from switchers because nonswitchers do not believe switching is desirable.[56] Nevertheless, several studies have attempted to measure the gains, if any, to switching for firms that have switched.[57] After adjusting for market factors, these studies have found generally that firms that switch from Nasdaq to NYSE or AMEX tend to have abnormally favorable performance prior to the announcement to list, mixed performance when the announcement to list is made, normal performance between the announcement date and the switching date, and abnormally negative performance after the switch in listing occurs. Overall, this combination of positive, normal, and negative performance for different event periods surrounding the decision to switch listing does not establish any conclusion about transactions costs for switchers.[58] The absence of any reliable finding of significantly reduced transactions costs for switchers undermines the claim that transactions costs are higher for Nasdaq/NMS firms that do not elect to switch.

[56] In fact, Cowan, Carter, Dark, and Singh (cited at note 57), find significant differences between the characteristics of eligible firms which switch and eligible firms which do not.

[57] See, for example, Gregory B. Kadlec and John J. McConnell, *The Effect of Market Segmentation and Illiquidity on Asset Prices: Evidence from Exchange Listings,* 49 J Fin 611 (1994); Theoharny Grammatikos and George Papaioannou, *Market Reaction to NYSE Listings: Tests of the Marketability Gains Hypothesis,* 9 J Fin Res 215 (1986); Gary C. Sanger and John J. McConnell, *Stock Exchange Listing, Firm Value and Security Market Efficiency: The Impact of Nasdaq,* 21 J Fin Quan Anal 1 (1986); Louis K-W. Ying et al., *Stock Exchange Listing and Securities Returns,* 12 J Fin Quan Anal 415 (1977); and James C. Van Horne, *New Listings and Their Price Behavior,* 25 J Fin 783 (1970).

[58] See, for example, William G. Christie and Roger D. Huang, *Market Structures and Liquidity: A Transactions Data Study of Exchange Listings,* 3 J Fin Intermediation 300 (1994). They compare spreads before and after switches in an attempt to measure the transactions costs of firms who switch listing and find a decline in spreads following switches. However, for the reasons discussed in Section III, spreads alone cannot be used to measure transactions costs. Also, see Michael Barclay, *Bid-Ask Spreads and the Avoidance of Odd-Eighth Quotes on NASDAQ: An Examination of Exchange Listings* (working paper, University of Pennsylvania, Wharton School, October 23, 1995).

TABLE 3

COMPARISON OF TRADING VOLUME 100 NASDAQ SECURITIES AND 100 NYSE/AMEX SECURITIES,* 1991

	Nasdaq Securities (%)	NYSE/AMEX Securities (%)
Unadjusted:		
Average volume†	17.3	5.2
Median volume†	12.5	4.2
Adjusted:‡		
Average volume†	8.7	4.7
Median volume†	6.3	3.8

* Based on the Christie and Schultz sample.
† Percent of shares outstanding.
‡ Based on 9.8% NYSE specialist participation rate and assumed 50% Nasdaq dealer participation rate.

The claim that transactions costs are higher on Nasdaq also has implications for trading volume. If this claim were correct, then, all else equal, investors would be more likely to trade NYSE/AMEX stocks because of the lower transactions costs. Thus, the volume of trading for comparable securities should be higher on NYSE/AMEX. To examine this, we analyzed the volume of trading for the 100 Nasdaq securities as well as the 100 comparably priced and similarly capitalized NYSE/AMEX securities Christie and Schultz studied. Table 3 presents our findings. We report the average and median trading volume for both Nasdaq securities and NYSE/AMEX securities on both an unadjusted and an adjusted basis; the adjusted statistics take into account differences in the extent of market maker participation.[59] We find that investors were more likely to trade Nasdaq securities than NYSE/AMEX securities. The behavior of these investors does not support the claim that transactions costs are higher for Nasdaq securities.[60]

[59] To adjust for market maker participation, we multiplied reported volume by $(1 - p)$ where p is the specialist participation rate (that is, the volume in shares of market maker purchases and sales divided by the total volume in shares of purchase and sales). For Nasdaq securities we assume a value of p equal to 0.50 because Nasdaq market makers participate on at least one side of every reported trade. For NYSE/AMEX securities, we assumed a value of p equal to the average NYSE specialist participation rate of 0.098; this is likely to understate p (and overstate adjusted volume) because other market participants also act as de facto market makers.

[60] Christie and Huang find that trading volume is significantly lower following changes in listing for firms who switch from Nasdaq to NYSE/AMEX. This finding is similar to ours and also suggests that transactions costs are higher on the exchanges. The authors argue that these volume figures must be interpreted with caution because of differences in how volume is reported on different markets, but do not make any adjustments to take these differences into account. See Christie and Huang (cited at note 58), at 314.

VII. Conclusion

Clustering occurs in competitive markets to reduce the transactions costs that would be incurred if assets were valued and priced with great precision. Precise quotes are less valuable than precise prices, so quotes cluster more than transactions prices. The amount of clustering depends on the structure of the market, the costs of precise valuations, the volatility of prices, and the size of transactions. For this reason, the degree of clustering varies across markets, among securities, and over time.

We have identified several financial markets—the London Stock Exchange, the London gold market, and the foreign exchange market—that have substantial clustering comparable to what is found on Nasdaq. We also find cross-sectional variation in the extent of clustering in these markets: yen-mark exchange quotes cluster less than either yen-dollar or dollar-mark quotes, and different stocks traded on the LSE have different degrees of clustering. These data support the competitive theory of clustering and demonstrate that neither the degree of clustering nor cross-sectional variation in the extent of clustering on Nasdaq is unusual.

We also examined intertemporal variation in clustering. We found that when all the data are examined, there is no support for the claim that an implicit pricing agreement collapsed when the collusion hypothesis was reported by newspapers. Instead, we found that sudden changes in spreads and the use of odd-eighth quotes are not unusual and do not appear to be correlated with these reports. In light of this evidence, the implausibility of collusion on Nasdaq, the inability of the collusion hypothesis to explain intramarket variation in clustering, and the evidence in favor of the competitive theory of clustering, we reject the hypothesis that Nasdaq clustering is attributable to collusion.

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