THE QUOTATION BEHAVIOR OF ECNs AND Nasdaq MARKET MAKERS

by

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ABSTRACT

We examine the impact of three Nasdaq rule changes on some aspects of market quality. In particular we investigate the quotation behavior of market makers following the reduction in tick size from eighths to sixteenths on June 2, 1997; the direct impact of including electronic communication network (ECN) quotes in the calculation of inside Nasdaq quotes; and the efficacy of the Actual Size Rule (ASR) during a time of market stress. We find that following the tick size reduction Nasdaq market makers again appear to be avoiding odd ticks (now odd sixteenths), but traders entering orders on ECNs appear to be more likely to use all ticks. We also find that ECNs establish the "inside market" and hence reduce trading costs for the public about 19% of the time. Finally, our findings suggest that the ASR led to a significant reduction in bid liquidity during the sharp market downturn of October 27-28, 1997. From a regulatory perspective, the results of our study suggest that while some of the market reforms have improved market quality, there are still major impediments to quote price competition and certain changes may have reduced liquidity. The nature of the data used in this study allows us to test three competing hypotheses for odd tick avoidance: natural "clustering" behavior; preferencing of order flow; and "tacit conspiracy" among oligopolistic market makers. We find no support for the natural clustering hypothesis and some inconsistencies with the preferencing hypothesis. Our findings are generally consistent with the tacit collusion hypothesis.

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I. Introduction

The publicity surrounding the finding of Christie and Schultz (1994) that Nasdaq market makers avoided odd-eighth quotes launched Securities and Exchange Commission (SEC) and Department of Justice (DOJ) investigations. The SEC investigation resulted in Nasdaq agreeing to adopt a series of order handling rule changes on January 20, 1997. The most significant of these changes was to include Electronic Communication Networks (ECNs) "quotes" (actually limit orders) in the Nasdaq national best bid and offer (NBBO) quote montage. ECNs such as Instinet existed prior to the rule change and were actively used by market makers to "lay off" positions, but only those firms with a direct connection to the ECN could see and access limit orders posted there.

The SEC rule changes also relieved Nasdaq market makers of the obligation to quote a minimum size (usually 1000 shares) for a group of stocks; the revised rule is known as the Actual Size Rule (ASR). As part of the DOJ settlement, Nasdaq market makers agreed to stop the convention of avoiding odd-eighths.[1] Barclay, Christie, Harris, Kandel, and Schultz (1998) report that spreads narrowed significantly following the rule changes. They further conclude that market makers had in fact stopped the convention of avoiding odd eighths.

The fact that traders were allowed to price limit orders entered on an ECN as fine as 1/256, but that these prices were rounded to 1/8 for inclusion in the NBBO, may have contributed in part to a movement in Congress to adopt smaller ticks, perhaps as low as $.01. As a result of congressional pressure, all U.S. stock markets adopted smaller ticks during 1997. On June 2, 1998 NASD adopted a 1/16 tick for trading stocks prices at or above $10 on Nasdaq.

This paper examines the impact of these rule changes on some important aspects of market quality. Given that Kandel and Marx (1997) show that odd-eighth avoidance is really odd-tick avoidance and that the DOJ settlement calls for market makers to stop avoiding odd-*eighths* not odd-ticks, we examine the quotation behavior of market makers following the reduction in tick size to 1/16. The nature of the data used in this study allows us to identify the source of the quote (either ECN or individual market maker name). We find that large market makers quote odd-sixteenths only about 7% of the time, small market makers quote odd-sixteenths about 0.5% of the time, while limit orders placed on ECNs are quoted in odd-

sixteenths about 11% of the time. We also find that when ECNs are *alone* at the inside spread, odd-sixteenths are quoted 49.3% of the time, which is close to what would be expected if all sixteenths were being used to form quotes. In contrast, during those relatively brief periods when large (small) market makers are alone at the inside spread, they use odd-sixteenths about 11.8% (24%) of the time, far less than the 50% that would be expected. Small market makers are so disinclined to be alone at the inside and so unlikely to quote odd ticks when they are, that we find the average small market maker quoting an odd tick while alone at the inside on a stock it quotes only six-tenths of a second per hour (vs. 6 seconds for the average large market maker and 190 seconds for the average ECN). Examining transaction price frequencies, we find that 32.6% of all trades are on an odd tick, less than the 50% level expected if all ticks are being used evenly. Overall, the percentage of odd tick trades exceeds the percentage of odd tick quotes, providing further evidence that odd tick quotes do not last long. Given our findings, we conclude that Nasdaq market makers appear again to be avoiding odd ticks.

The nature of the data also allows us partially to test competing hypotheses that seek to explain odd-tick avoidance. The natural clustering hypothesis reasons that humans prefer round numbers. Since even ticks are "more round" than odd, odd ticks will be observed less often than the 50% "expected". Thus, we would expect ECNs, large market makers, and small market makers to exhibit roughly the same low level of odd-tick quote usage. We do not find this to be true and thus reject this hypothesis.

The preferencing hypothesis states that preferenced order-flow arrangements reduce the incentive for dealers to compete on price. Therefore, we would expect to find a higher occurrence of odd-tick usage among dealers without large amounts of preferenced order flow - generally small market makers. In contrast, the tacit-collusion hypothesis predicts that small market makers will exhibit the same or a greater degree of odd-tick avoidance, since they are afraid of retribution from their larger competitors. As detailed above, we find a much lower occurrence of odd-ticks among small market makers. The infrequency of inside-alone quotes and general odd-tick avoidance exhibited by small market makers is generally consistent with a fear of retribution by larger market makers, but it is inconsistent with the preferencing hypothesis. We interpret this result as support for the tacit collusion hypothesis. Recent evidence suggests that Nasdaq market makers are still engaging in anti-competitive practices.[2] Therefore, given that ECN quotes are anonymous and Nasdaq quotes are not, our findings

[1] U.S. v. Alex. Brown & Sons, Inc., et al. April 22, 1997.

[2] See Nasdaq Press Release dated November 3, 1998 titled "NASD Regulation sanctions Olde trader for ant-competitive harassment of a Nasdaq market maker, firm also fined." According to the press release, a market maker was disciplined for harassing another market maker who narrowed the spread.

suggest that Nasdaq spreads are not as narrow as they could be in a market where market makers could reveal there reservation prices without fear of retribution.

The fact that ECN "quotes" use more odd-sixteenths than market maker quotes leads us to directly examine the contribution ECNs have made to the narrowing of quotes reported by Barclay, et al. We do this by measuring the percentage of time that ECNs are alone at the inside bid or offer. The intuition is that if ECN quotes were not included in the NBBO the inside spread would be wider. We find that one or more ECNs is alone (i.e., with no market maker quoting the same price) at the inside (either the bid or ask) about 19% of the time. Therefore, ECN quote inclusion directly reduces trading costs for the public about one-fifth of the time. Alternatively, given that ECN quotes are typically anonymous market maker orders, our findings can be interpreted as further evidence that market makers are more likely to reveal their true reservation prices if they can do so anonymously.

The final contribution of this paper is to examine the impact of the ASR on market liquidity during a time of market stress (the downturn of October 20-31, 1997). Nasdaq, following the crash of 1987, enacted the minimum quoted size rule. Christie and Schultz (1996) show that the minimum quoted size rule was effective in maintaining liquidity during the market break of November 15, 1991. In early 1997, however, Nasdaq implemented a pilot test of eliminating minimum quoted size requirements on certain stocks under a rule called the Actual Size Rule ("ASR"), which has since been extended to all stocks and been made permanent. We compare the aggregate inside quotation size of stocks subject to the ASR to that of comparable stocks not subject to the ASR during the "turbulent market" of October 20-31, 1997 and contrast the results with those of a control period. We find that ask sizes increased while bid sizes decreased, which would be expected during a market downturn. However, we find that bid sizes were reduced by a statistically significant larger percentage for the ASR stocks.

The remainder of this paper is organized as follows. Section II provides a literature review and a description of the market reforms. Section III describes our data and methodology. Section IV presents our results, while Section V contains concluding remarks.

II. Relation to Previous Literature

Nasdaq market makers came under close academic, media, and regulatory scrutiny following the publication of Christie and Schultz (1994). They show that Nasdaq market makers systematically avoided using odd-eighth quotes in 71 of the 100 most active Nasdaq stocks during 1991.

The literature contains various explanations for the findings of Christie and Schultz. As first suggested by Harris (1991) the clustering hypothesis states that coarse pricing grids reduce transaction costs by minimizing both negotiation time and information transfer. Christie and Schultz test whether Harris' clustering hypothesis explains their results and conclude that it does not.

Grossman, Miller, Cone, Fischel, and Ross (1995) propose a variation of Harris' suggestion as an explanation for the observed pattern of Nasdaq quotes. They state that it is human nature to cluster on round numbers and cite evidence from the real estate market where price is typically negotiated in $1,000 increments. Since dealers typically negotiated for trades on SelectNet and Instinet where pricing increments as small as 1/64 were allowed and used, during the Christie-Schultz sample period, this "natural clustering" hypothesis seems an unlikely explanation for the findings of Christie and Schultz.

Godek (1996) and to a lesser degree Huang and Stoll (1996) argue that preferencing and payment for order flow prevent quotes from narrowing to one tick, therefore 1/8 spreads will be relatively uncommon. The intuition is that a lack of time priority rules on Nasdaq force dealers to compete for order flow on dimensions other than price. Assuming a 2/8 spread market, a dealer who narrows the spread to 1/8 will cause other dealers to quote-match.[3] Therefore, preexisting orderflow arrangements will prevent the narrowing dealer from attracting additional order flow. Hence, there is no incentive to narrow spreads beyond 2/8. This in turn will cause diminished usage of odd-eighths.

It is interesting to note that a lack of time priority alone could cause the type of single-tick avoidance suggested by Godek. Cordella and Foucault (1996) develop a model that suggests that dealers have less incentive to price compete (which leads to narrower spreads) under a random priority rule than under a time priority rule. The intuition is that under a random priority rule there is a positive probability that a dealer will get the next order. Under a time priority rule, the quotes ahead of him in the queue need to be filled before he can obtain an execution. Thus, a random priority rule, which best describes Nasdaq, will result in lower price competition and hence wider spreads.[4]

Kandel and Marx (1997) develop a model that is close in spirit to Cordella and Foucault (1996). Kandel and Marx show that for stocks with ten or more market makers (typical

[3] See Harris (1994) for a discussion of quote matching.

[4] Panchapagesan (1997) and Angel and Weaver (1998) show empirically that a lack of time priority results in lesser price competition than in a sharing priority system. A sharing priority system is similar to a random priority system in that both systems allow quote-matching dealers to have much higher probabilities of execution than under a time priority system.

of the active Nasdaq listings studied by Christie and Schultz) there generally exist two Nash equilibrium spreads. The smaller equilibrium spread will be the roundtrip market-making costs rounded up to the next tick. The larger spread will be one tick wider than the smaller spread. They argue that dealers "prefer the equilibrium with the higher spread." Kandel and Marx point out that their model predicts restricting quotes to either odd-eighths or even-eighths. The same applies to the other previously mentioned models predicting wider spreads.

While Cordella and Foucault implicitly assume no preferencing of order flow, Kandel and Marx show that if all dealers have preferenced order flow the number of Nash equilibriums increases. However, they argue that if some dealers do not have preferenced order flow, and if some unpreferenced order flow exists, then the two Nash equilibrium result holds since some dealers will have an incentive to price compete.

In a world where tick sizes have fallen to one-sixteenth and many stocks have much higher typical spreads, it may be best to read the "preferencing" argument a bit more broadly than the literal recounting of models above suggests. The Cohen-Maier-Schwartz-Whitcomb (1981) model of spread equilibrium in the absence of artificial minimum tick sizes shows that each stock has a "natural" bid-ask spread (that may vary from time to time) to which the actual spread returns when perturbed. Since that natural equilibrium spread is not one-sixteenth for all stocks at all times, the preferencing argument alone cannot explain the avoidance of $3/16^{th}$, $5/16^{th}$, etc. prices. However, the natural clustering hypothesis *combined with* the "preferencing" hypothesis suggests that quoters who prefer "round numbers" at the beginning of a negotiation will not be forced by competitive pressures to resort to fine increments in order to garner order flow. We prefer to interpret the "preferencing" hypothesis in this light to avoid setting up and demolishing a straw man.

Christie and Schultz (1994) interpret their findings as evidence of tacit collusion among Nasdaq market makers. Transcripts of taped conversations between market makers support their hypothesis.[5] Dealers were recorded berating other dealers who narrowed the spread creating what was called in the industry a 'Chinese market.' In contrast to both the Godek model and the Kandel-Marx model, the tacit collusion hypothesis would argue that fear of retribution by competitors prevents dealers, including those without preferenced order flow, from competing on price.

Christie, Harris, and Schultz (1994) report that after the urging of Nasdaq CEO Ketchum to narrow spreads, dealers did. As part of the Department of Justice settlement (see U.S. v. Alex. Brown & Sons, Inc., et al. April 22, 1997) dealers agreed to stop the convention of

avoiding odd-***eighths.*** Barclay et al. (1998) examine odd-eighth quote usage on the same sample of stocks as Christie and Schultz but for the period November 2, 1996 to January 17, 1997. Their Figure 3 shows a highly significant decline in the avoidance of odd-eighths for their study period.

Kandel and Marx (1997) examine a group of small Nasdaq stocks with 1/16 tick sizes during January 1994 and demonstrate that odd-eighth avoidance is really odd tick avoidance. Our paper examines the propensity of dealers to avoid odd-tick quotes after the reduction of Nasdaq ticks from 1/8 to 1/16 on June 2, 1998. The nature of our data also allows us to examine the quotation behavior of individual market makers and ECNs. In contrast, Christie and Schultz could only examine NBBO quotes. Thus, our data allow us to test the preferencing, natural clustering, and tacit collusion hypotheses as possible explanations for odd-tick avoidance.

The preferencing hypothesis is tested by comparing the quotation behavior of small versus large market makers. Larger market makers are more likely to enter into preferencing arrangements to obtain order flow. Therefore, we might expect them to engage in less price competition and hence quote odd-ticks less often than smaller market makers in the absence of tacit collusion. The preferencing hypothesis would therefore predict that small market makers would quote odd-sixteenths more often than larger market makers.

Examining the quotation behavior of Nasdaq market makers when trading anonymously as contrasted with their public quotes allows us to test the natural clustering and tacit collusion hypotheses. Nasdaq market makers have long used limit orders posted anonymously on ECNs to "lay off" their inventory positions. Since the Order Handling Rules were implemented, these market maker orders (but not the orders of other brokers or of institutions) *must* be displayed as quotes, but the quotes are attributed to the ECN. That is, market maker limit orders posted on ECNs are still anonymous, but they are no longer invisible; when these orders are priced at or inside the best market maker public quote, they join or establish the NBBO. If the natural clustering hypothesis of Grossman et al. is correct, we would expect the same pattern of odd-tick usage on ECNs as we find on Nasdaq. In contrast, given the anonymity of ECN quotes and the fact that publicly displayed ECN quotes are typically market maker orders, the tacit-collusion hypothesis would predict a higher percentage of odd-sixteenth usage in ECN quotes than in market maker quotes.

An additional contribution of this paper is that we examine the effect that inclusion of ECN "quotes" in the Nasdaq NBBO has had on the bid-ask spread. Barclay et al. (1998) report

[5] See SEC (1996)

that spreads narrowed an average of 30% following the adoption of new Order handling Rules on January 20, 1997. Included in the major features of the rules are the inclusion of ECNs and public limit orders in the calculation of the NBBO. We are able to separate ECN quotes from market maker quotes and thus measure the contribution of ECNs to the reported narrowing of spreads. This paper can, in this respect, be seen as an extension of Barclay et al.

Finally, we examine the competition among dealers to provide liquidity during times of market stress. Following the crash of 1987, dealers agreed to honor their quotes for orders up to 1,000 shares. Christie and Schultz (1995) examine the efficacy of this rule during the market stress period of 1991. They find the 1,000 share quote minimum was sufficient to maintain liquidity during this market downturn. The ASR provision of the Order Handling Rules replaced the 1,000 share quote minimum with a 100 share minimum on January 20, 1997 for a pilot group of 50 stocks. Although Barclay et al. find that the reduction in the minimum quoted size reduced the average depth of quotes, they conclude that the reduction did not appear to adversely affect investor transaction costs. This paper complements Christie and Schultz (1995) and Barclay et al. (1998) by examining the effect of the reduction in minimum quoted size during another period of market stress, October 1997.

III. Data and Methodology

The ultimate data source for quotes was the Nasdaq National Quote Distribution System (NQDS) real-time data feed. These data were "captured" and archived on CD-ROMs by Automated Trading Desk, Inc., which supplied them to us. The archive consists of every quote and quote update (market maker or ECN ID, price, side and size, time-stamped to the second by a network clock synchronized to the nuclear clock) by every market maker and ECN for all Nasdaq stocks. Transaction data were obtained from the NYSE Trade And Quote database.

The NQDS feed is used to calculate the National Best Bid and Offer (NBBO). Although the Order Handling Rules implemented in early 1997 required the inclusion of market maker limit orders posted on ECNs in the calculation of the NBBO, non-market makers are given discretion concerning ECN order disclosure. Allowing undisclosed orders is common. The Paris Bourse and the old Toronto CATS both allow for undisclosed orders (for a discussion of undisclosed orders, see Harris (1996)). SEC (1998) reports that of the non-market maker posted ECN limit orders that could have improved the NBBO, only 6% chose to have their orders disclosed. In addition, if an ECN has a tick size smaller than $1/16^{th}$, then buy (sell) orders posted at prices that are not an integer multiple of $1/16^{th}$ are rounded to the sixteenth below (above) the actual limit price before being transmitted over the NQDS feed. Therefore,

while our data represent publicly available quotes, they do not include all ECN orders at their quoted price.

The stocks included in our study are the same as those included in Barclay et al. (1998) Specifically, we include the 50 stocks which NASD included in the Order Handling Rules pilot program (begun January 20, 1997) which were subject to the Actual Size Rule ("First 50"), as well as the 50 stocks included in the second phase of the Order Handling Rules pilot program (begun February 10, 1997) but which continued to have 1000 share minimum proprietary quote sizes ("Second 50"). Data for some of the original 100 stocks are no longer available due to mergers, moves to other trading venues, etc. This reduced our sample to 44 stocks from the First 50 and 42 – 44 stocks (depending on the day) from the Second 50. Of the 88 stocks in our sample, all but one was subject to a 1/16 tick. Informix Corp had a trading range that subjected it to a 1/32 tick. We therefore excluded it from tests involving odd-sixteenth avoidance.

The 10 largest stocks in the First 50 chosen by NASD are also the 10 largest Nasdaq stocks, while the 10 largest stocks in the Second 50 rank 11-20 in size, so these two groups cannot be compared for many purposes. The NASD reported in its proposal to the SEC for implementing the Order Handling Rules and the Actual Size Rule Pilot that the remaining 40 stocks in each group (the "First 40" and the "Second 40" respectively) were selected by stratified random sample from the next 480 largest Nasdaq stocks. Thus, the First 40 and the Second 40 should constitute reasonably comparable samples. Accordingly, we disaggregate our sample, and report results for each of these four groups separately. However, following NASD Economic Research (1997), most of our text discussion of the disaggregated samples focuses on the First 40 vs. Second 40 comparison.

Due to the amount of data involved, we limit our study to two 10-day periods. We use data from September 15-26, 1997 as our 'normal' period and October 20-31, 1997 as our 'market stress' period. Using our data, we create a dynamic quote montage. To validate our computational method, we compare our inside quotes with the inside prices transmitted by Nasdaq as part of the NBBO.

Recall that the natural clustering hypothesis predicts that ECN and market maker quotes should have the same relative percentage of odd-tick usage. In addition, recall that the preferencing hypothesis predicts that smaller, more price-competitive, dealers should quote odd-ticks a higher percentage of the time than larger dealers. Finally, the tacit collusion hypothesis predicts that market maker orders represented as anonymous ECN quotes should exhibit a higher frequency of odd-sixteenth usage than market maker quotes. Accordingly we disaggregate our data and examine the quotes posted by three groups: ECNs, large market

makers, and small market makers. During the time of our study, there were four ECNs posting quotes: Bloomberg Trade Book; Instinet; Island, and Terra Nova. We define our *large* market maker group as the ten Nasdaq market makers making markets in the largest number of stocks in our sample on the first day, September 15, 1997. The *small* market maker group is comprised of those dealers making markets in 5 -10 Nasdaq stocks from our sample of 87.[6] There are 23 such market makers.

For each group we calculate the time-weighted average of odd-sixteenth quotes for each member (ECN or market maker). To take into account the number of stocks an ECN or market maker quotes, we then weight each member's time-weighted average by the number of stocks the member quotes from each sample. We examine the propensity to quote odd-ticks in all 87 stocks, as well as those in the First 10, First 40, Second 10, and Second 40. While we initially average over all quotes, the quotation behavior of all three groups at the inside is examined as well. We separate cases where a member of a group is at the NBBO with others from cases where the entity is alone. To examine if patterns evidenced in the large market maker group are systematic across firms; we also examine each large market maker.

Chan, Christie, and Schultz (1995) and Barclay et al. (1998) document systematic temporal differences in Nasdaq inside spread widths. In particular they find that spreads at the end of the day are narrower than at the open. This suggests a higher frequency of odd-tick usage at the end of the day. To test this hypothesis we disaggregate our data by hour of the trading day.

To examine if odd tick quoting patterns are also true for *trades*, we calculate the percentage of odd tick trades overall, for each stock group, and by trading hour. Since larger trades are more likely to be negotiated, and roughly one half of the 1,000 share trades probably represent daytraders hitting a market maker posted quote, we also disaggregate trades into less than, equal to, and greater than 1,000 share groups.

The contribution of ECNs to the narrowing of spreads reported by Barclay et al. (1998) is measured by calculating the proportion of the time ECNs are alone at the inside. We separately measure the average proportion of the time that 1, 2, 3, 4, or any number (1-4) of ECNs are alone at the inside. Since market makers and daytraders have a tendency to use different ECNs, and given the different trading behavior of each group, we examine each ECN individually.

[6] We did not choose the very smallest market makers (those making markets in 1 – 4 stocks in our sample) because our selection procedure would have created a small sample problem by putting excessive weight on observations from sparse data.

To examine the effect of the ASR on quoted size; we calculate the time-weighted average inside size across all market makers or ECNs.[7] We then determine the relative contribution of each group to aggregate size. Finally, we contrast the size data for the normal period to those for the "market stress" period and document differences between the two periods.

IV. Results

A. Odd-sixteenth quotation behavior of market makers and ECNs

Since there are 16 allowable quotation price "slots" in a dollar and 8 are "odd" (1/16th, 3/16th,…,15/16th), under a random distribution hypothesis the expected frequency of odd sixteenth quotations by a market maker or ECN is 50%. Following the tradition established by Christie and Schultz (1994), we first determine the frequency of odd-sixteenth inside quotes for the 87 stocks in our sample. Figure 1 plots the number of stocks with a given percentage of odd-sixteenth quotes. Less than ten percent of the stocks in our sample have greater than 40% odd-sixteenth quotes, while five have no odd-sixteenth quotes at all. The extent of odd-tick avoidance evidenced by Figure 1 is not as dramatic as that reported in Christie and Schultz (1994).. However, the distribution of frequencies is clearly skewed left, which is in stark contrast to the right-skewed distribution of odd-eighth frequencies illustrated in Figure 3, Panel C of Barclay et al. Both Barclay et al. and our study include the same stocks. However, Barclay et al. study them before the Nasdaq tick size reduction, while our study period is after the reduction.

To further investigate odd-tick avoidance by market makers and ECNs for our sample of stocks, we next disaggregate the data into ECNs, large market makers, and small market makers and determine the average percentage of odd-tick quotes for each group. Under the hypothesis that both odd and even ticks are being used in equal numbers, the expected frequency of odd-tick quotes is 50% for each group. In addition, the natural clustering hypothesis states that the percentage of odd tick quote usage should be equal across all three groups.

Panel A of Table 1 summarizes our results averaged over the day. Overall, we find ECNs quote in odd ticks 10.6% of the time, large market makers 6.7% of the time, and small market makers only 0.5% of the time. We perform both parametric and non-parametric

[7] The Chicago Stock Exchange also quotes some Nasdaq stocks. Since it is neither a market maker nor an ECN, its average size is calculated separately.

significance tests (note reported). We take two differences: (1) the difference between the sample average frequency of odd ticks and 50%; and (2) the difference between the odd-sixteenth quote frequency of each group. In each case, we perform three significance tests: a Student t parametric test and two non-parametric tests: the sign test and the Wilcoxon sign rank test. The latter test assumes that the distribution is symmetric while the former does not [see Wolfe and Hollander (1973) and Stuart & Kendall (1961)]. The difference from both "null" hypotheses is clearly significant, both statistically and economically, leading us to reject both hypotheses. Our findings therefore do not support the natural clustering hypothesis.

However, the frequency of odd-sixteenth quotations listed in the first three columns includes all quotations regardless of whether the price is at, inside or away from the NBBO "inside" price. It may well be that quotes posted *away* from the inside are more likely to be at even sixteenths (round numbers in our context), since such quotes are not intended to be competitive. In addition, ECNs, while they are significantly more likely to quote odd ticks, only have a 10.6% frequency of odd ticks (again for all quotations). Thus, we need to look into quotation behavior in much more detail.

Looking at the frequency of odd ticks conditional on the quoter being at the inside (Table 1, Panel A, columns 5-7) we see that, on average, large market makers quote odd ticks 11.5% of the time that they are on the inside, clearly a higher frequency than for quotes at all prices, but still significantly below 50%. Small market makers quote odd ticks 8.1% of the time that they are on the inside. By contrast, ECNs quote odd ticks 34.8% of the time that they are on the inside; this proportion is significantly higher than that of either large or small market makers. Again, the differences between groups and from the 50% odd "expectation" are statistically significant. To the extent that large market makers are more apt to have preferenced order flow than small market makers, we can test the preferencing hypothesis as an explanation for our results.

. Recall that the preferencing hypothesis predicts that the degree of price competitiveness of market makers is inversely related to the amount of preferenced order flow they obtain. Anecdotal evidence suggests that larger market makers are more likely to have order flow preferencing arrangements than small market makers. In addition, economic logic suggests that larger market makers are more likely to have orderflow preferencing arrangements due to the substantial economies of scale and scope in the "market" for the purchase of orderflow. Therefore, small market makers should be more price competitive and quote odd-sixteenths with a higher frequency than large market makers. Comparing the

frequency of odd-sixteenth usage at the NBBO by large market makers to small market makers reveals that the reverse is true. This does not support the preferencing hypothesis.

However, our findings are consistent with the tacit collusion hypothesis. Recall that the tacit collusion hypothesis suggests that the propensity of market makers to freely use all sixteenths is related to the degree of retribution they will receive from other market makers. Given the anonymity provided by ECNs, the tacit collusion hypothesis would then predict that market makers would use odd-sixteenths more often on ECNs than they do for Nasdaq quotes. Non-market maker broker-dealers and institutions can choose to have their limit orders displayed in the ECN "quote", but they are not required to do so. SEC data (reported on page 106 of File No. S7-12-98 17 CFR Parts 201, 240, 242 and 249) show that only 6% of the orders not subject to mandatory display are actually displayed. Hence, most of the ECN "quotes" actually represent market maker limit orders. As previously discussed, ECN quotes (market maker limit orders) contain odd-sixteenths 34.8% of the time that they are on the inside versus 11.5% and 8.1% for large and small market makers respectively. This is consistent with the tacit collusion hypothesis. It further suggests that although quotes narrowed following the order handling rules, they could be narrower still if the fear of retribution did not exist among market makers.

Although increased regulatory oversight may reduce the fear of retribution, it may not sufficiently remove it.[8] A system that enables anonymity for *all* quotes may reduce the fear of retribution more than increased regulatory oversight and hence produce narrower spreads. However given the current predominant Nasdaq trading method of bilateral telephone negotiations and the requisite identification of counterparties -- such a system is not feasible.

The last three columns of Panel A provide the frequency of odd tick quotes conditional on the quoter being ***strictly alone*** at the inside (with no other ECN or market maker present). For those cases, the difference between market maker and ECN quoting behavior is most striking. Large (small) market makers quote odd ticks only 11.7% (23.9%) of the time that they are alone on the inside, whereas ECNs quote odd ticks 49.3% of the time that they are alone inside. This huge difference between market maker and ECN behavior is surprising given the fact that a substantial proportion of ECN "quotes" are market maker own-account layoff orders[9].

[8] See footnote 2.

[9] Non-market maker broker-dealers and institutions can choose to have their limit orders displayed in the ECN "quote", but they were not required to do so during our sample period. SEC data [reported on page 106 of File No. S7-12-98 17 CFR Parts 201, 240, 242 and 249] show that only 6% of the orders not subject to mandatory display are actually displayed. Hence, since non-market makers rarely displayed their orders in the ECN quote during our sample period, most of the ECN "quotes" actually represent market maker limit orders.

Why is it that market makers do not use odd ticks when they are quoting but do use them when they are entering anonymous own-account orders to close positions?

Clearly, natural clustering arguments based on "human nature" cannot explain the difference in behaviors for market maker and ECN quotes. On the other hand, this behavior is consistent with the "tacit collusion" hypothesis. Since limit orders placed on an ECN are anonymous, a market maker cannot be accused by his colleagues of "making a Chinese market" (hurting other market makers by narrowing the spread) when he places an order priced at an odd sixteenth in that venue.

Further evidence regarding market maker propensities to quote odd ticks comes from disaggregating our samples by whether or not the Actual Size Rule applies. Rows 2-5 of Panel A report these data. The surprising result here is that First 40 stocks (subject to the Actual Size Rule) have a markedly lower sample average frequency of market maker odd-sixteenth quotes relative to Second 40 stocks for every group. For example, the sample average frequency of odd-sixteenth quotes at the inside by a large market maker is 6.6% for First 40 stocks and rises to 9.7% for Second 40 stocks. The difference is statistically significant. What explains this difference? Since the two groups of 40 stocks were chosen by NASD using stratified random sampling, the only overall difference between the two groups should be the fact that the Actual Size Rule reduces the mandatory quote size (and, as we will show, the actual average aggregate inside quote size) for the First 40.[10] Thus, the observed lower propensity to quote odd ticks found in First 40 stocks is consistent with the hypothesis that the Actual Size Rule reduces the size of the inventory positions market makers build up partly as a result of activities by "SOES daytraders" and hence reduces the aggressiveness with which they have to lay off these positions.

The 23.9% frequency of odd-sixteenth quotes for small market makers alone at the inside is much larger than the 11.7% for large market makers and thus would seem to support the preferencing hypothesis. The fact that small market makers quote in odd-ticks, while alone at the inside, more often than large market makers would also seem to indicate that small market makers are not afraid of retribution. Further, small market maker odd-tick percentages approach those of ECNs, while alone at the inside, for First 10 and Second 10 stocks. This would initially seem to refute the tacit collusion hypothesis. However, the probability of

[10] Barclay, et al. (1998) do report in footnote 6 that the First 50 had a higher proportion of stocks where market makers avoided odd eighths prior to January 20. Since they do not disaggregate their sample further, we do not know whether their finding applies to the First 40 vs. the Second 40. However, our data suggest that the First 10 appear to have a *higher* propensity for odd-sixteenth market maker quotes, so it is likely that the pre-January-20 results were caused by a 40 vs. 40 difference.

retribution from creating a "Chinese" market is not merely a function of quoting in odd-ticks, but also ought to be a function of 1) length of time the quoter is alone at the inside with an odd quote, 2) whether the quoter created a new price or merely "quote matched" and was left alone after others changed their quotes. Our data do not distinguish between "active" and "passive" quote positions. However, we can calculate the average length of time an entity was quoting odd alone at the inside. We find that on average small market makers quote odd while alone at the inside only 0.6 seconds of every trading hour.[11] By contrast, large market makers quote odd while alone at the inside about 6 seconds of each trading hour. For ECNs, the number is 190 seconds. While none of the numbers is very large, small market makers in particular face a low probability of retribution if they create a "Chinese" market less than 1 second each hour. The results can thus be interpreted as not being in conflict with the tacit collusion hypothesis.

The next piece of evidence as to when market makers are and are not willing to quote in odd ticks comes from examining their behavior hour by hour over the trading day. Panel B of Table 1 shows quotation behavior by hour (except 9:30 – 10:00, the normally very active first half-hour) for the 2-week period studied. In general, the frequency of odd-sixteenth quotes for ECNs and large market makers, whether at all prices, at the inside, or inside alone, rises steadily over the trading day. For example, only 8.9% of large market maker inside quotes are at odd ticks in the 9:30 – 10:00 period, while 13.1% of inside quotes are at odd ticks during the 3:00 – 4:00 period. The increase in price competition, as the day matures, is consistent with the idea that market makers want to "go home flat". Daytraders seek to reverse their positions as soon as they acquire them [see Harris & Schultz (1998)], so they should not exhibit the same temporal increase in price competition as market makers.

Of the four ECNs in our study, two are most frequently used by market makers (Instinet and Bloomberg TradeBook, while the remaining two ECNs are used mainly by daytraders (Island and TerraNova). Examining the odd tick quoting patterns of the individual ECNs (not reported here, but available from the authors) reveals that the ECNs mainly used by market makers exhibit an increasing proportion of odd tick quotes as the day matures. By contrast, the other two ECNs do not display a clear time-of-day pattern. This supports our contention that market makers are more price competitive as the day matures. In addition, the fact that both market-maker preferred ECN and large market-maker odd-sixteenth quotes increase as the day progresses suggests that market makers <u>do</u> use their quotes, at least to a modest extent, to

[11] We obtain this measure by multiplying the number of seconds in a trading hour (3600) times the average percentage of an hour that small market makers are alone at the inside (not reported in a table but 0.0687%) times the percentage of that time that small market makers quote odd (23.9% from Table 1.)

effect their layoff strategies. While ECNs may be a more important venue for market maker layoff trading, we can see no explanation for the increasing frequency of odd-sixteenth market maker quotes as the day progresses other than that this results from more aggressive layoff activity. While market-maker preferred ECN and large market maker odd-sixteenth quotes exhibit clear time-of-day patterns, small market maker odd-sixteenth quotes do not, as shown by Panel B of Table 1. One possible explanation of this may be that most of the (rare) instances of small market makers being alone inside at an odd price are due to passive, rather than active, quote behavior.

The findings here are consistent with Chan, Christie, and Schultz (1995) and Barclay et al. (1998)'s finding that spreads tighten over the day. All of these behaviors result from the tendency of market makers to lay off more aggressively toward the end of the day in order to "go home flat". The result is more competitive pricing: even market maker quotes get more competitive late in the day. Again, it is hard to explain this behavior by the natural clustering hypothesis of Grossman et al. (1997) - why does "human nature" change each day toward 4PM?

Table 2 reports the sample average frequency of odd-sixteenth quotes by individual large market maker (names omitted). Panel A contains the overall results, and by stock group while Panel B disaggregates by trading hour. The results are broadly consistent with our findings above, but these data show considerable variation among market makers (MM#) in their propensity to quote odd ticks. MM10 appears to have the lowest propensity to quote odd ticks (2%), followed by MM8 (3.1%), while MM4 has the highest propensity (10.6%) followed by MM1 (9.7%). All market makers but one (MM9) show a clear tendency to increase their frequency of odd tick usage as the trading day progresses, and most (7 of the 10) show a lower propensity to quote odd ticks for First 40 than for Second 40.

Thus far, we have only examined odd tick *quotes*. As Christie and Schultz (1994) point out, if *trades* occur evenly on all ticks then the fact that *quotes* avoid odd ticks would be irrelevant. Accordingly, we examine the percentage of trades on odd ticks for each of our stock groups. We disaggregate the data by trade size, with trades of less than, strictly equal to, and greater than 1,000 shares examined separately. Trades greater than 1,000 shares are examined as a group since they are more likely to be negotiated than smaller trades. Harris (1991) suggests that coarse trading grids reduce the cost of negotiation. As Christie and Schultz (1994) and Porter and Weaver (1998) point out the benefits of negotiation (a better price than posted quotes) vary directly with trade size and are more likely to outweigh the fixed costs

of negotiation (time and information transfer) the larger the trade size; hence we would expect larger trades to be more frequently observed on odd ticks relative to smaller trades.

Trades of exactly 1,000 shares are examined separately, since 1,000 shares is the most frequent size used by day traders. As Harris and Schultz (1998) point out, day traders typically open their positions by hitting a market maker quote and then attempt to reverse their positions by posting a limit order on an ECN. If roughly one half of the 1,000 share trades result from orders hitting a market maker's quote, since we show that market makers infrequently quote odd ticks, we would expect 1,000 share trades to exhibit the a very small percentage of odd tick quotes.

Comparing odd tick trades and quotes will also allow insight into the duration of odd tick quotes. If market makers seek to avoid odd tick quotes, then those that occur (on ECNs or other market makers) will be taken out quickly. This in turn will cause the percentage of odd tick trades to be higher than the percentage of odd tick quotes. The results are contained in Table 3. As a point of reference, we also report the time-weighted average of odd-tick quotes at the NBBO inside. All market maker and ECN quotes are included in this average.

Panel A of Table 3 contains averages over the day. The percentage of aggregate odd-tick trades is greater than the percentage of odd-tick quotes for both the First 40 and Second 40 groups. This suggests that odd-tick quotes are indeed taken out soon after they occur for those stock groups. By contrast, the aggregate percentage of odd-tick trades for both the First 10 and Second 10 stock groups is less than the percentage of odd-tick quotes, suggesting that odd-tick quotes are tolerated more in those groups. This is consistent with the findings reported in Table 1 for those groups. Recall that the percentage of odd-tick inside quotes was largest for these two groups and that the percentage of time that the ECNs and small market makers were quoting odd while alone at the inside is over 50% for the First and Second 10 stocks. It then becomes clear that very large Nasdaq stocks are benefiting more from increased price competition than the medium-sized stocks.

Examining the percentage of odd trades by trade size reveals that, consistent with our hypothesis regarding the way daytraders effect their trades, trades of exactly 1,000 shares exhibit a much smaller percentage of odd-tick prices than larger or smaller trades. Also, trades of more than 1,000 shares exhibit a greater propensity to occur on odd ticks than trades less than 1,000 shares. This is consistent with the hypothesis that larger trades get better prices than smaller trades.

In Panel B, we further disaggregate the trade data by looking at each trading hour separately, as well as before the open and after the close. It is clear that there is a higher

proportion of odd tick trades in the afternoon than in the morning, which is consistent with our previous finding that price competition increases throughout the day. However, the most striking result of this panel is that the proportion of odd-tick trades jumps dramatically after the market close when only displayed quotes on ECNs are visible. This further supports our hypothesis that dealers wish to go home flat.

B. Percentage of time ECNs are alone "inside"

If one or more ECNs are the only entities quoting the best bid (say), ECNs may be said to be alone on the inside. This is evidence of the power of the Order Handling Rules, since any market maker filling a retail customer order (e.g., pursuant to a payment for order flow arrangement with the customer's broker) must match the ECN price under "best execution" rules. When the Order Handling Rules were first implemented, the fraction of the time ECNs were alone at the inside was relatively low. For example, for the 24 days following February 24, 1997, Nasdaq statistics show that ECNs were alone at the inside 8.2% of the time. However, once the tick size fell to one-sixteenth, it was to be expected that ECNs would be alone at the inside more often since tick size is inversely related to price competition (see Cordella and Foucault (1996)). NASD's statistics for the period from the June 2, 1997 move to sixteenths to August 31, 1997 show ECNs alone about 14 - 18% of the time for First 50 stocks[12]. NASD statistics for all 2900 stocks subject to the Order Handling Rules show ECNs alone inside 10.1% of the time (for a 15-day period following September 15, 1997).

Our results reported in Table 4 cover the 10-trading-day period September 15-26, 1997 and the stocks of the First 50 and the Second 50. We find that, for this set of stocks and this time period, ECNs are alone at the inside a very high percentage of the time, 19.0% (Panel A). As noted above, this helps explain why the Order Handling Rules reduced spreads so much (and why spreads fell again on June 2 when sixteenths came in).

Table 4 disaggregates the data in several ways. First is by the number and identity of ECNs inside alone. Since there were four ECNs subject to the Order Handling Rules at the time our data were collected, it is possible to observe exactly one, exactly two, exactly three, or all four ECNs inside at a time when no market makers are inside. Not surprisingly, Panel A of Table 4 shows that, of the 18.9% of the time when one or more ECNs are alone inside, 17.9% of the time there is only one. Most often Instinet is on the inside without market maker company

[12] The percentages are approximate because they are from a graph posted on NASD's Web site (read 11/17/97).

(15.1% of the time), followed by Island (1.8%), Bloomberg Trade Book (0.8%) and Terra Nova (0.2%).

Disaggregating by side (bid vs. ask) yields the somewhat surprising result that ECNs are more likely to be inside alone on the ask (20.1% of the time) than on the bid (17.9% of the time) during this period.

We also disaggregate by whether stocks are subject to the Actual Size Rule (ASR) or not (Panel A). There is a slight tendency for Second 50 stocks (not subject to the ASR) to have higher inside alone percentages. A possible reason for expecting less aggressive ECN pricing in First 50 stocks is that the ASR reduces SOES day-trading activity somewhat and, as Dubinin and Whitcomb (1997) and Harris and Schultz (1998) show, SOES day-traders use ECNs aggressively to lay off positions. However, except for Island, ECNs did not require traders other than market makers to display their limit orders during our sample period. Thus, any tendency of day-trader limit orders to pull ECNs inside more often for Second 50 than for First 50 stocks is likely to remain hidden. In this connection, it is interesting that ISLD is inside alone about 43% more often for Second 50 stocks.

The most interesting disaggregation is by time of day (Panel B). Here, there is a very clear tendency for ECNs not to be on the inside alone during the first half-hour of trading and for them to be on the inside alone more often during the last hour of trading. The reason almost certainly lies in the layoff-trading behavior of market makers. As Figure 5 in Barclay, et al. (1998) shows, Nasdaq spreads are widest as price discovery begins just after the market opens at 9:30 AM. The spread drops precipitously up to 10:00 AM, declines slowly during the day until about 3:30 PM, and then drops precipitously again during the last half-hour of trading. Such behavior is consistent with the common presumption that market makers, like other day-traders, do not like to hold positions over night. Since increasingly urgent layoff activity is likely to be evidenced by increasingly competitive limit orders on ECNs, we should not be surprised to observe the ECN inside-alone percentage rising as the day progresses.

Given that ECN quotes are largely market maker limit orders, the findings reported in this section provide further evidence in support of the tacit collusion hypothesis. If a market maker quote is alone at the inside it may be that he is creating a “Chinese Market” and can then expect retribution from other market makers. Anonymity prevents retribution, therefore if a market maker fears retribution from narrowing the spread, he can avoid it by placing a limit order on an ECN instead of posting a quote in Nasdaq. The fact that the two ECNs most frequently used by market makers are increasingly alone at the inside as the trading day progresses can then be seen as consistent with the tacit collusion hypothesis.

The fact is that the data we present here understate the true percent of the time that ECNs are alone on the inside. The reason is that if an ECN limit order betters the best market maker quote by less than one-sixteenth, the Nasdaq quote montage and the NBBO never display that fact. In addition, if an institution or a non-market-maker trader posts a limit order on an ECN but that order is not displayed, it will not be reflected in the NBBO. Only by keeping a time-stamped electronic record of actual ECN "books" and comparing them to the publicly-displayed quotes (which neither Nasdaq nor most ECNs make possible) could we measure the true extent to which ECNs improve on market maker quotes[13].

C. Aggregate inside quotation size of market makers and ECNs

One measure of Nasdaq market liquidity is the total number of shares which could be executed automatically at any instant at the NBBO "best" price.[14] NASD (1997) introduced and Barclay, et. al. (1998) used the following specific implementation of this notion: Sum the total number of shares bid and offered by market makers and ECNs at the NBBO each second of the trading day and compute a time-weighted average. We use the same measure here.[15]

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[13] Dubinin and Whitcomb (1997) look at this issue in a different way; they study the extent to which the layoff limit orders of one medium-sized SOES day-trading firm would narrow the NBBO spread if they were displayed in the fine increments (down to 1/64th) on which they were posted on various ECNs.

[14] Like all measures of liquidity, this one is imperfect. This measure may understate liquidity by excluding the larger fills market makers may be willing to provide to favored customers (institutions and retail brokers with whom the market maker has a payment for order flow arrangement). It may overstate liquidity in that a queue of orders awaiting the expiration of a 17-second permitted delay following an earlier execution against a market maker which elected not to change its quote may be ahead of any new order submitted now.

[15] The problem with summing the shares bid at the inside price (say) by market makers is that infrequent very large bid sizes can have an inordinate impact on sample mean aggregate sizes. This might be fine if these large quotes were "real", but SOES rules enable a dealer quoting size over 1000 shares to "move his quote" before having to fill orders equal to the entire size quoted. [NASD rules require a dealer to honor his entire quoted size if an order is presented by telephone or via SelectNet preferencing, and NASDR enforces this "Firm Quote Rule" more aggressively than was the case prior to the NASD-SEC settlement. However, individual orders presented via SOES cannot exceed 1000 shares, and SOES is programmed to allow a dealer 17 seconds following execution of one order against its quote before having to take another; accordingly, quoted sizes in excess of 1000 shares are partially illusory. We thank Dean Furbush, Chief Economist of the NASD, for correcting our earlier misunderstanding of this rule.] Thus a more realistic measure of aggregate electronic liquidity may be what we call "Aggregate Truncated Size", the sum over market makers of the portion of their quote sizes not exceeding 1000 shares. For example, if 3 market makers are quoting bid sizes of 100, 1000, and 10,000 respectively, their "Aggregate Size" is 11,100 and their "Aggregate Truncated Size" is 2100. We find that the results for Aggregate Truncated Size are qualitatively similar to those for Aggregate Size. The results for Aggregate Truncated Size are not reported here, but are available from the authors upon request.

Averaging aggregate bid sizes and aggregate ask sizes and averaging over time can conceal interesting phenomena. For example, it is reasonable to predict that, during times of market stress, some market makers may reduce their quote sizes *on the side of the market that is under pressure* to the maximum extent permitted by NASD rules, competitive pressures and their need to represent customer limit orders in their Nasdaq quotes. We are fortunate that a period of very substantial market turbulence occurred while we were preparing this paper, and we naturally seized the opportunity to study how market maker quote sizes responded to this turbulence. However, we would miss the opportunity for comparison altogether if we were to aggregate data inappropriately. Accordingly, we break out aggregate size by (1) side, (2) half-hour period, and (3) ASR status during the period of stress, Monday October 20 – Friday October 31, 1997 and compare the results to our more normal "control" period, September 15 – 26, 1997.

C.1. September results.

Table 5 presents our summary results averaged over stocks for the two weeks September 15 – 26, 1997, the "control" period. We report the (time-weighted) average number of market makers on the inside and the (time-weighted) average size on the inside. Average inside size is reported separately for market makers, ECNs, and the Chicago Stock Exchange (which is neither a conventional market maker nor an ECN). Total size is the simple sum of the three component venue sizes. Since the average aggregate size of each component venue is time-weighted, each average reflects the influence of periods when the component venue is not at the inside; hence, the very small average aggregate size reported for the Chicago Stock Exchange. This contrasts with a measure of average size *conditional* on the venue being at the inside. Data for the First 50 stocks (subject to the ASR) are reported separately from data for the Second 50 and compared. Because the presence of the 10 largest Nasdaq stocks in the First 50 makes that group not strictly comparable to the Second 50, we also follow NASD's Economic Research Department in comparing NASD's two size-matched stratified random samples of 40 stocks, the "First 40" and the "Second 40".

The first fact that stands out in Table 5 is how thin the inside market is. For example, for First 50 stocks in September, the average number of market makers at the inside ask is 2.4 and at the inside bid is 2.5. The average sizes are 1740 shares (ask) and 1941 shares (bid). This is striking given the fact that the First 50 stocks include the 10 largest Nasdaq stocks and together comprise about 37% of Nasdaq dollar volume (based on Nasdaq statistics from the period prior

to January 20, 1997). When we exclude the top 10 stocks, the "First 40" show average sizes of 1598 (ask) and 1798 (bid).

Second 50 stocks also have a thin inside market in September, but whether measured by average number of market makers or average inside size, these stocks (smaller but not subject to the ASR) have somewhat larger inside markets.[16] The average inside size of First 50 stocks ranges from 82.2% to 87.5% of that of Second 50 stocks. When we exclude the top 10 stocks, the comparison is even more striking – the average inside size of "First 40" stocks ranges from 80.3% to 84.9% of the equivalently-measured average inside size of "Second 40" stocks. The differences are statistically significant.

The second fact that is apparent is that average market maker inside size has diminished over time for both groups and ECN size has risen. For example, for First 50 stocks, Barclay, et. al. (1998). report average market maker size of 3656 shares in the period Feb. 10 – 28, 1997; that diminishes in our study to 1840 (average of bid and ask sizes) for September 15 – 26, 1997. By contrast, average aggregate ECN inside size for First 50 stocks was only 243 shares in February, while it had risen to 660 in September.

C.2. October results.

Tables 6 and 7 report the main results of trading over the turbulent period October 20-31 and compare them with the September results. We do not have data, of course, for the two periods on Monday October 27 (approximately 2:35PM – 3PM and 3:30PM to the close) during which the entire market was shut down, and we have very sparse Instinet data for a period on October 27 (roughly 9:30AM – 11:00 AM) during which Instinet was experiencing severe order handling difficulties. Accordingly, October 27 has less weight than other days in the averages reported in Panel A of Table 6, and Instinet has less weight in the ECN averages on that day. In the half-hour-by-half-hour results reported in Table 7, we exclude the periods 2:30-3:00 and 3:30–close altogether, since the amount of data is so sparse that any averages would tend to mislead.

Panel A of Table 6 reports the combined results for the entire 10-trading-day period, October 20-31 in a format similar to Table 5 and compares them to the September results contained there. Market makers clearly reduced the average aggregate size of their quotations

[16] It is fair to point out that Second 50 stocks had larger inside markets before the rule change as well; see Table II, Panel A in Barclay, et al. (1997.) The size of the difference is rather surprising given the sample construction procedure. A partial explanation (accompanied by another mystery) is offered in Barclay, et. al. (1997) footnote #6. The authors note that the First 50 sample contains a larger fraction of stocks whose dealers avoided odd-eighth quotes (prior to the Order Handling Rules).

in October. In the same side, same group comparisons (next to last column), October sizes ranges from 69.5% to 89.7% of their September counterparts. Perhaps the most interesting results come from comparing the October results for the NASD's two control groups in its Pilot Test of the Actual Size Rule. Whereas in September First 40 ask size was 80.3% that of the Second 40, in October the proportion was 85.4%, an increase. On the other hand, First 40 bid size was 85% that of the Second 40 in September vs. only 80.7% in October. Since the market's general direction was down in late October and since the sharpest changes were negative, this result is consistent with the hypothesis that market makers will reduce the size of their quotes on the side of the market that is under stress if they are free to do so.

Panel B of Table 6 takes a closer look at October 27, the day the market experienced extreme downward pressure and had to close twice. In one sense, the Nasdaq market did very well on October 27. Market maker average aggregate size did not collapse, and First 10 stocks showed impressive market maker and ECN sizes.[17] However, when we compare First 40 average aggregate sizes with those for Second 40 stocks, we see that October 27 did exact a toll. Whereas in September, market maker bid quotes for First 40 stocks averaged 85% of the aggregate size of those for Second 40 stocks, on October 27 market maker First 40 quotes were only 76% as large. By contrast, market maker ask quotes for First 40 stocks were 81.1% as large as their Second 40 quotes (vs. 80.3% in September).

In Table 7, we disaggregate further by looking at half-hour periods. Table 7 contains the same measures as Table 6 except that we add a column showing the percent change in the Nasdaq Composite Index over each half-hour (beginning at the time shown in the column to the left of the Index Change). Over the course of October 27, we see a volatile, but generally consistent picture. To save space, we look only at First 40 stocks, comparing them with the Second 40 in the last column. Especially toward the latter part of the day (when the trend had become rather clear), we see that First 40 average aggregate market maker bid sizes tend to be quite small relative to the Second 40, whereas First 40 ask sizes generally remain at or above their September percentages. During some periods of the day (for example, 11-11:30 AM when the market fell 1.2% and 3-3:30 PM when the market fell 1.8%), October 27 First 40 average aggregate market maker bid size is as little as 63% - 67% of September Second 40 bid size.

[17] There were a few very large First 10 bid quotes, which overstated size but did not account for the entire effect. An examination of Aggregate Truncated Size [see footnote 15 for a discussion of possible overstatement in aggregate size and for the definition of "Aggregate Truncated Size"] shows that First 10 stocks had rather large market maker quotes most of the day. ECN sizes for First 10 stocks were especially impressive considering the fact that Instinet, by far the largest ECN, was effectively shut down from about 9:30 – 11:00.

These results are consistent with the hypothesis that market makers will reduce their quotes on the side of the market that is experiencing stress when they are free to do so. Putting it differently, it appears that mandatory minimum quotation sizes do effectively force market makers to provide more liquidity to the market, especially at times of market stress[18].

VI. Conclusion

The most striking finding in this paper is clearly that market makers still have an extreme tendency to avoid odd intervals in their advertised (Nasdaq) quotations. The same firms, when they come to lay off positions on ECNs [Dw1](and, to a lesser extent, in their advertised quotations toward the end of the day) appear more willing to quote odd ticks. This behavior does not appear to be consistent with the natural clustering hypothesis that it is human nature to quote in round numbers even in highly competitive atomistic markets. This behavior does appear to be consistent with imperfect competition in advertised quotations. Comparing the frequency of odd-tick quotations for small versus large market makers and ECNs allows us to test the competing imperfect competition hypotheses of "tacit collusion" and "preferencing" as explanations for odd-tick avoidance. Certainly, the fact that the avoidance of odd-increment quotes exists in the part of the Nasdaq market where most order flow is "preferenced" (directed to certain market makers either pursuant to payment for/internalization of retail order flow arrangements or pursuant to institutional brokerage relationships) and does not exist in the portion of the marketplace where order-price competition prevails is most telling.

Further, the fact that ECNs appear to have a greater propensity to avoid odd ticks than market makers can be interpreted as evidence in favor of the "tacit collusion" hypothesis, since the anonymous feature of ECN quotes removes the fear of retribution from other market makers. If a system were developed that allowed *all* quotes to be displayed anonymously, we might see an increase in odd-increment advertised quotations and a further reduction in bid-ask spreads.

The Order Handling Rules, by bringing market maker limit orders posted on ECNs into the NBBO, have both narrowed the NBBO bid-asked spread (thereby lowering the profitability of purchase of retail order flow) and have tended to obscure the odd-sixteenth behavior of market

[18] In a competitive market, economic theory would imply that if market makers are forced to maintain minimum quotation sizes, fewer market makers will participate in equilibrium. However, NASD Economic Research (1997) shows that the number of firms making markets in Second 40 stocks has been trending upward at the same rate over 1997 as it has for First 40 stocks. Whether this is merely a short-run phenomenon or the result of an imperfectly competitive market is a subject for further investigation.

makers. We can no longer uncover these behavior patterns merely by looking at distributions of "inside spread" increments [i.e., by trivial replication of Christie & Schultz (1994)'s methodology using 16 increments rather than 8]. Accordingly, a major focus of this paper is to decompose the NBBO "inside" by looking separately at ECNs and market makers. In the course of doing this, we uncover the important role now played by ECNs. Fundamentally, ECNs are the main venue where quote price competition occurs in the Nasdaq market. Specifically, we find that one or more ECNs are alone on the inside (i.e., with no market maker(s) quoting the "best" price) 19% of the time.

We also find that ECNs are more likely to be alone on the inside toward the end of the trading day and are more likely to "quote" odd ticks toward the end of the trading day. Both findings reflect the importance that market makers and other day-traders place on closing positions before the end of the trading day and the fact that ECNs are the principal venue for the fierce price competition among traders that accompanies the daily unwinding of positions.

Our results also have some implications for a policy issue which was facing the SEC when we began this work – whether to permit market makers to show any size they wish when they are entering proprietary quotes (the Actual Size Rule) rather than having to post a mandatory size that is 1000 shares for most stocks in our sample[19]. On that issue, we find that market maker aggregate average inside size is only 80.3% to 85% as large for First 40 stocks (which were subject to the Actual Size Rule during our sample period) as for Second 40 stocks (which were not), a difference that is statistically significant and that should not result from sampling differences, since these two samples were picked by NASD via stratified random sampling from stocks ranked 21 – 500 in trading volume as of the sample selection date.

We also find that market maker aggregate average inside size is significantly smaller in late October 1997(when the market was under severe stress) for all stock groups we studied. The greatest decrease in size comes in the Bid size for First 40 stocks, which falls from 85% of that for Second 40 stocks in September to 80.7% in October and to as little as 63% - 67% of September Second 40 aggregate bid size during the periods on October 27, 1997 when the market was falling most precipitously. This is consistent with the hypothesis that market makers will reduce the liquidity they offer to the side of the market that is under stress when they are free to do so.

[19] On July 15, 1998, the SEC decided to extend the ASR to all Nasdaq stocks effective July 20.

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Table 1: ODD TICK QUOTATION FREQUENCIES

This table reports the sample average percentage of the time that ECNs and market makers (MMs) quote odd tick prices (1/16th, 3/16th,…,15/16th). The data cover the period September 15 - 26, 1997 and include all quotes made in First 50 and Second 50 stocks by 4 ECNs, the 10 largest market makers, and 23 small market makers. The expected frequency is 50% under the "null" hypothesis that traders do not discriminate between odd and even sixteenths (1/8th, 2/8th,…,7/8th). Panel A reports odd sixteenth frequencies for all quotes, quotes while at the inside, and quotes where the quoter is alone at the inside. Panel A also disaggregates by stock group (First 10,…,Second 40). Panel B contains hour-by-hour averages over the trading day. Of the original 100 stocks 12 merged or ceased trading before our study and one was subject to a 1/32 tick size. Therefore, the sample size is 87.

GROUP	Frequency Of Odd tick Quotations (%):								
	At All Prices			At NBBO Inside			At Inside Alone		
	ECNs	Large MMs	Small MMs	ECNs	Large MMs	Small MMs	ECNs	Large MMs	Small MMs
A. Average Over The Day									
Overall	10.6%	6.7%	0.5%	34.8%	11.5%	8.1%	49.3%	11.7%	23.9%
First 10	32.2%	18.4%	1.9%	45.4%	27.2%	31.1%	67.7%	15.4%	66.7%
First 40	5.9%	4.0%	0.2%	28.8%	6.6%	3.9%	42.7%	10.1%	16.4%
Second 10	18.1%	12.5%	0.9%	38.7%	19.8%	19.5%	61.8%	14.6%	58.6%
Second 40	9.4%	5.7%	0.3%	33.5%	9.7%	4.1%	50.9%	12.2%	20.4%
B. Average by Trading Hour									
9:30 -10:00	7.2%	5.4%	0.4%	31.2%	8.9%	10.1%	44.9%	10.6%	21.9%
10:00-11:00	10.1%	6.1%	0.5%	33.7%	10.2%	8.4%	47.0%	10.7%	20.6%
11:00-12:00	11.0%	6.7%	0.5%	36.2%	11.4%	7.5%	50.6%	10.7%	23.5%
12:00-1:00	11.0%	7.0%	0.4%	35.9%	12.6%	6.2%	52.0%	11.5%	32.4%
1:00-2:00	11.2%	6.9%	0.4%	35.9%	11.8%	7.4%	49.5%	12.6%	23.3%
2:00-3:00	11.7%	7.2%	0.5%	34.1%	12.0%	7.2%	49.0%	13.2%	22.5%
3:00-4:00	11.8%	7.6%	0.5%	35.6%	13.1%	9.9%	50.8%	12.8%	27.4%

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Table 2: ODD TICK QUOTATION FREQUENCIES BY LARGE MARKET MAKER

This table reports the sample average percentage of the time that the 10 top market makers (MMs) quote odd tick prices (1/16th, 3/16th,…,15/16th). The data cover the period September 15 - 26, 1997 and include all quotes made in First 50 and Second 50 stocks by the 10 largest market makers. The expected frequency is 50% under the "null" hypothesis that traders do not discriminate between odd and even sixteenths (1/8th, 2/8th,…,7/8th). Panel A reports odd sixteenth frequencies for all quotes. Panel A also disaggregates by stock group (First 10,…,Second 40). Panel B contains hour-by-hour averages over the trading day. Of the original 100 stocks 12 merged or ceased trading before our study and one was subject to a 1/32 tick size. Therefore, the sample size is 87

GROUP	Frequency Of Odd tick Quotations (%):									
	MM1	MM2	MM3	MM4	MM5	MM6	MM7	MM8	MM9	MM10
A. Average Over The Day										
Overall	9.7%	6.4%	6.5%	10.6%	9.1%	7.0%	6.7%	3.1%	3.7%	2.0%
First 10	29.5%	13.1%	19.7%	26.5%	16.8%	20.8%	18.9%	9.4%	12.4%	7.8%
First 40	5.3%	5.2%	2.6%	6.6%	5.6%	3.6%	4.8%	0.7%	2.1%	1.2%
Second 10	14.7%	10.1%	16.4%	16.2%	14.4%	11.5%	14.9%	13.9%	7.9%	4.4%
Second 40	8.6%	5.2%	5.0%	9.7%	9.7%	6.2%	3.8%	1.5%	2.3%	0.9%
B. Average by Trading Hour										
9:30 -10:00	7.0%	4.9%	5.9%	9.6%	7.2%	5.9%	4.2%	2.8%	3.1%	1.4%
10:00-11:00	8.3%	5.3%	6.6%	10.0%	8.0%	6.8%	5.3%	2.6%	3.7%	1.6%
11:00-12:00	9.1%	6.9%	6.4%	10.5%	8.9%	6.8%	6.5%	3.1%	4.6%	1.7%
12:00-1:00	10.2%	6.8%	6.2%	10.9%	9.6%	6.7%	6.9%	3.2%	4.3%	2.1%
1:00-2:00	10.4%	5.8%	6.2%	10.5%	9.8%	6.9%	7.5%	3.5%	2.9%	2.3%
2:00-3:00	10.6%	7.2%	6.2%	10.5%	9.7%	7.2%	7.8%	3.2%	3.4%	2.2%
3:00-4:00	11.1%	7.3%	7.5%	11.7%	9.8%	8.0%	7.4%	3.4%	3.4%	2.6%

Table 3: ODD TICK TRANSACTION FREQUENCIES

This table reports the sample average percentage of transactions at odd ticks (1/16th, 3/16th,…,15/16th). The data cover the period September 15 - 26, 1997 and include all transactions in First 50 and Second 50 stocks. For reference, the percentage of NBBO inside quotes on odd ticks is also reported for each group. Panel A reports odd tick transaction frequencies overall as well as for different trade sizes. Panel A also disaggregates by stock group (First 10,…,Second 40). Panel B contains hour-by-hour averages over the trading day. Of the original 100 stocks 12 merged or ceased trading before our study and one was subject to a 1/32 tick size. Therefore, the sample size is 87.

GROUP	Percentage of Quotes at the NBBO inside on Odd Ticks	Number of Transactions by Trade Size				Percentage of Transactions that are at Odd Ticks			
		All Trades	<1,000	=1,000	>1,000	All Trades	<1,000	=1,000	>1,000
A. Average Over The Day									
Overall	22.3%	1,399,580	843,648	371,244	184,688	32.6%	34.0%	27.9%	35.5%
First 10	43.4%	863,412	562,412	201,834	99,166	36.3%	36.8%	33.7%	39.2%
First 40	17.1%	160,676	87,070	47,358	26,248	24.1%	25.4%	20.8%	25.7%
Second 10	31.6%	167,168	90,990	51,628	24,550	29.9%	32.2%	22.3%	37.2%
Second 40	21.4%	208,324	103,176	70,424	34,724	25.7%	27.7%	20.0%	31.0%
B. Average by Trading Hour									
Before open		8,874	3,412	2,550	2,912	17.6%	16.1%	15.5%	21.4%
9:30 -10:00	17.3%	223,918	139,964	57,526	26,428	27.8%	29.7%	22.1%	30.4%
10:00-11:00	20.9%	238,426	140,660	67,790	29,976	32.5%	34.8%	26.6%	35.3%
11:00-12:00	22.2%	170,282	103,704	44,372	22,206	33.6%	35.1%	29.1%	35.7%
12:00-1:00	22.8%	147,220	89,820	36,698	20,702	35.2%	36.3%	31.2%	37.6%
1:00-2:00	22.8%	157,310	95,636	41,120	20,554	33.2%	34.3%	29.2%	36.5%
2:00-3:00	23.3%	182,382	110,254	49,266	22,862	34.0%	35.3%	29.6%	36.8%
3:00-4:00	24.4%	253,186	151,256	68,770	33,160	33.2%	34.1%	29.4%	36.9%
After Close		17,982	8,942	3,152	5,888	39.8%	39.9%	37.9%	40.6%

TABLE 4: ECNs ALONE AT INSIDE SPREAD -- FIRST 50 AND SECOND 50 STOCKS

This table reports the percentage of the time that one or more ECNs are ALONE at the inside ("best") bid or offer price during the 10-trading-day period September 15 - 26, 1997. "One or more ECNs alone" means that no market maker is quoting the inside price. Panel A reports the percentages broken out by ECN (for 4 ECNs, not including the Chicago Stock Exchange) and by the number of ECNs at the inside. The column labeled overall is the sum of the columns labeled 1, 2, 3, 4. The data are also disaggregated by Group (First 50 vs. Second 50) and by Side (Bid vs. Ask). Panel B contains averages hour-by-hour over the trading day. The number of observations used to compute the average is the number of stocks times the number of days. Of the original 100 stocks 12 merged or ceased trading before our study sample period. Therefore, the maximum daily sample size is 88.

Group	Side of Quote	N	Percentage of Time ECN is Alone at Inside:								
			By Number of ECNs Alone at Inside					By ECN			
			1	2	3	4	Overall	Bloomberg Trade Book	Instinet	Island	Terra Nova
A. Average Over The Day											
Overall	**Either**	1736	17.9%	1.1%	0.053%	0.0019%	19.0%	0.8%	15.1%	1.8%	0.2%
	Ask	868	18.8%	1.2%	0.054%	0.0016%	20.1%	0.9%	15.7%	2.0%	0.2%
	Bid	868	16.9%	1.0%	0.053%	0.0023%	17.9%	0.7%	14.4%	1.7%	0.1%
First 50	**Either**	880	17.7%	1.0%	0.062%	0.0022%	18.8%	0.9%	15.2%	1.5%	0.2%
	Ask	440	19.6%	1.2%	0.073%	0.0030%	20.9%	1.2%	16.5%	1.7%	0.2%
	Bid	440	15.8%	0.9%	0.051%	0.0015%	16.8%	0.6%	13.8%	1.3%	0.1%
Second 50	**Either**	856	18.0%	1.1%	0.045%	0.0017%	19.2%	0.7%	14.9%	2.2%	0.2%
	Ask	428	18.0%	1.2%	0.035%	0.0002%	19.2%	0.5%	14.9%	2.3%	0.3%
	Bid	428	18.0%	1.1%	0.055%	0.0031%	19.1%	0.8%	15.0%	2.0%	0.1%
B. Average by Trading Hour											
9:30 -10:00	**Either**	1736	13.3%	0.8%	0.034%	0.0012%	14.1%	0.4%	10.8%	2.1%	0.1%
10:00-11:00			17.9%	1.3%	0.072%	0.0033%	19.2%	0.9%	14.5%	2.3%	0.2%
11:00-12:00			18.2%	1.1%	0.074%	0.0035%	19.3%	0.7%	15.5%	1.8%	0.2%
12:00-1:00			17.5%	1.0%	0.048%	0.0015%	18.5%	0.7%	14.9%	1.7%	0.2%
1:00-2:00			17.9%	1.0%	0.050%	0.0021%	19.0%	1.0%	15.1%	1.6%	0.2%
2:00-3:00			18.6%	1.1%	0.042%	0.0008%	19.7%	1.0%	15.8%	1.6%	0.2%
3:00-4:00			19.4%	1.2%	0.045%	0.0008%	20.6%	0.9%	16.6%	1.8%	0.2%

Table 5: AVERAGE AGGREGATE INSIDE QUOTATION SIZE FOR ECNs & MARKET MAKERS

First 50 & Second 50 Stocks, SEPTEMBER 15 - 26, 1997

This table reports the average aggregate size (in hundreds) of the "inside" quotations of ECNs and market makers (MMs) during the 10-trading day period September 15 - 26, 1997. The Chicago Stock Exchange (CHX) is examined separately. The data are broken out by Side (Ask vs. Bid) and by Group (First 10, Second 10, First 40, Second 40), and market maker average aggregate sizes are compared to total size and to Group 2 size (e.g., First 50 vs. Second 50). Of the original 100 stocks 12 merged or ceased trading before our study sample period. Therefore, the sample size is 88.

Side	Group	Average Aggregate Size in Hundreds of Shares						
		Average number of MMs on the Inside	Average MM Size on the Inside	Average ECN Size on the Inside	Average CHX Size on the Inside	Average Total Size on the Inside	MM Percentage of Total	MM Size - First Group as Percentage of Second Group
ASK	First 50	2.366	17.395	7.399	0.006	24.800	70.1%	82.2%
	Second 50	2.567	21.169	8.183	0.002	29.354	72.1%	
BID	First 50	2.534	19.406	5.793	0.001	25.200	77.0%	87.5%
	Second 50	2.712	22.175	7.483	0.001	29.658	74.8%	
ASK	First 10	3.483	23.780	17.846	0.028	41.655	57.1%	90.3%
	Second 10	3.329	26.329	13.282	0.003	39.614	66.5%	
BID	First 10	3.749	25.818	15.082	0.005	40.905	63.1%	98.4%
	Second 10	3.320	26.244	13.894	0.001	40.140	65.4%	
ASK	First 40	2.118	15.976	5.078	0.001	21.055	75.9%	80.3%
	Second 40	2.379	19.890	6.919	0.002	26.812	74.2%	
BID	First 40	2.264	17.981	3.729	0.000	21.710	82.8%	85.0%
	Second 40	2.562	21.166	5.894	0.000	27.061	78.2%	

Table 6: AVERAGE AGGREGATE INSIDE QUOTATION SIZE FOR ECNs & MARKET MAKERS

First 50 & Second 50 Stocks, OCTOBER 20 - 31, 1997 vs. SEPTEMBER 15 - 26, 1997

This table reports the average aggregate size (in hundreds) of the "inside" quotations of ECNs, the Chicago Stock Exchange (CHX), and market makers (MMs) during the turbulent market of October 20-31, 1997 and contrasts these data to the "control" 10-day trading period, September 15 - 26, 1997. The data are disaggregated by Side (Ask vs. Bid), by Group (First 10, Second 10, First 40, Second 40), and by day. Market maker average aggregate sizes are compared to total size and to Group 2 size (e.g., First 10 v. Second 10). Panel A contrasts data for the entire 10-trading day October period with data from Panel A, Table 2, while Panel B contrasts data for October 27, 1997 with the full October and September periods, breaking Oct. 27 data out by half-hour period. The "Index Chg." data for October 27 are based on the Nasdaq Composite Index. Of the original 100 stocks, 12 merged or ceased trading before our study. Therefore, the sample size is 88.

Side	Group	Average Aggregate Size in Hundreds of Shares								
		Average number of MMs on the Inside	Average MM Size on the Inside	Average ECN Size on the Inside	Average CHX Size on the Inside	Average Total Size on the Inside	MM Percentage of Total	MM Size - First Group as Percentage of Second Group	MM October size as a Percentage of September Size	MM October Size as a Percentage of September Second Group Size
A. October 1997 vs. September 1997										
		October 1997 Results							**October vs. September**	
ASK	**First 10**	2.952	19.571	16.519	0.042	36.132	54.2%	106.9%	82.3%	74.3%
	Second 10	2.579	18.302	14.788	0.001	33.091	55.3%		69.5%	
BID	**First 10**	3.214	22.271	15.399	0.037	37.707	59.1%	104.3%	86.3%	84.9%
	Second 10	2.878	21.347	12.969	0.005	34.321	62.2%		81.4%	
ASK	**First 40**	1.881	14.362	4.699	0.002	19.064	75.3%	85.4%	89.9%	72.2%
	Second 40	2.101	16.811	6.475	0.001	23.287	72.2%		84.5%	
BID	**First 40**	2.002	15.322	3.975	0.002	19.298	79.4%	80.7%	85.2%	72.4%
	Second 40	2.303	18.994	5.637	0.001	24.632	77.1%		89.7%	

Table 6: (Continued)										
Side	Group	Average Aggregate Size in Hundreds of Shares								
		Average number of MMs on the Inside	Average MM Size on the Inside	Average ECN Size on the Inside	Average CHX Size on the Inside	Average Total Size on the Inside	MM Percentage of Total	MM Size - First Group as Percentage of Second Group	MM October size as a Percentage of September Size	MM October Size as a Percentage of September Second Group Size
B. October 27, 1997 vs. September 1997										
		October 27, 1997 Results							October 27 vs. September	
ASK	First 10	2.481	17.553	11.266	0.000	28.820	60.9%	114.2%	73.8%	66.7%
	Second 10	2.045	15.367	9.631	0.000	24.999	61.5%		58.4%	
BID	First 10	2.829	25.694	9.449	0.031	35.173	73.0%	123.7%	99.5%	97.9%
	Second 10	2.608	20.775	7.650	0.000	28.425	73.1%		79.2%	
ASK	First 40	1.610	13.081	3.002	0.011	16.094	81.3%	81.1%	81.9%	65.8%
	Second 40	1.913	16.126	5.258	0.000	21.384	75.4%		81.1%	
BID	First 40	1.833	14.990	2.195	0.001	17.186	87.2%	76.0%	83.4%	70.8%
	Second 40	2.234	19.728	3.968	0.000	23.696	83.3%		93.2%	

Table 7: AVERAGE AGGREGATE INSIDE QUOTATION SIZE FOR ECNs & MARKET MAKERS
First 40 Stocks - October 27, 1997 vs. September 1997

This table reports the average aggregate size (in hundreds) of the "inside" quotations of ECNs, the Chicago Stock Exchange (CHX), and market makers (MMs) during the turbulent market of October 27, 1997 and contrasts these data to the "control" 10-day trading period, September 15 - 26, 1997. The data are for First 40 Stocks only and are disaggreagted by side and half hour period. Market maker average aggregate sizes are compared to total size and to Group 2 size. The "Index Chg." data for October 27 are for the Nasdaq Composite Index. Of the original 100 stocks 12 merged or ceased trading before our study. Thus, the sample size is 88.

Side	Average Aggregate Size in Hundreds of Shares								
	Start Time	Index Change	Average number of MMs on the Inside	Average MM Size on the Inside	Average ECN Size on the Inside	Average CHX Size on the Inside	Average Total Size on the Inside	MM Percentage of Total	MM Size - First Group as Percentage of September Second Group
ASK	930	*-0.295%*	1.909	17.154	1.342	0.066	18.562	92.4%	66.0%
	1000	*-0.403%*	2.076	16.829	2.570	0.076	19.475	86.4%	72.7%
	1030	*-0.627%*	1.903	16.660	1.831	0.000	18.490	90.1%	81.0%
	1100	*-1.190%*	1.606	11.455	5.076	0.000	16.531	69.3%	80.0%
	1130	*0.240%*	1.932	14.900	5.229	0.000	20.129	74.0%	88.4%
	1200	*-0.152%*	1.802	14.056	4.039	0.000	18.095	77.7%	77.2%
	1230	*-0.577%*	1.757	13.538	4.860	0.000	18.398	73.6%	95.5%
	1300	*-1.165%*	1.884	16.250	3.853	0.000	20.103	80.8%	95.3%
	1330	*-0.555%*	1.925	13.980	5.805	0.000	19.785	70.7%	92.1%
	1400	*0.370%*	1.990	16.319	3.075	0.000	19.395	84.1%	84.6%
	1430		**Market Closed**						**Market Closed**
	1500	*-1.804%*	1.801	16.227	0.879	0.000	17.107	94.9%	75.6%
	1530		**Market Closed**						**Market Closed**
BID	930	*-0.295%*	2.099	16.589	1.361	0.011	17.961	92.4%	70.1%
	1000	*-0.403%*	2.169	18.111	0.812	0.001	18.923	95.7%	67.1%
	1030	*-0.627%*	2.378	19.060	2.298	0.000	21.358	89.2%	89.6%
	1100	*-1.190%*	2.155	18.129	2.922	0.000	21.051	86.1%	63.0%
	1130	*0.240%*	2.227	19.410	2.766	0.000	22.176	87.5%	96.3%
	1200	*-0.152%*	1.997	16.215	3.589	0.000	19.805	81.9%	98.9%
	1230	*-0.577%*	1.964	15.737	2.376	0.000	18.113	86.9%	70.2%
	1300	*-1.165%*	2.307	19.240	2.977	0.000	22.217	86.6%	73.5%
	1330	*-0.555%*	2.182	17.206	3.792	0.000	20.999	81.9%	79.1%
	1400	*0.370%*	1.906	14.571	4.544	0.000	19.115	76.2%	81.2%
	1430		**Market Closed**						**Market Closed**
	1500	*-1.804%*	2.054	17.547	0.556	0.000	18.103	96.9%	67.0%
	1530		**Market Closed**						**Market Closed**

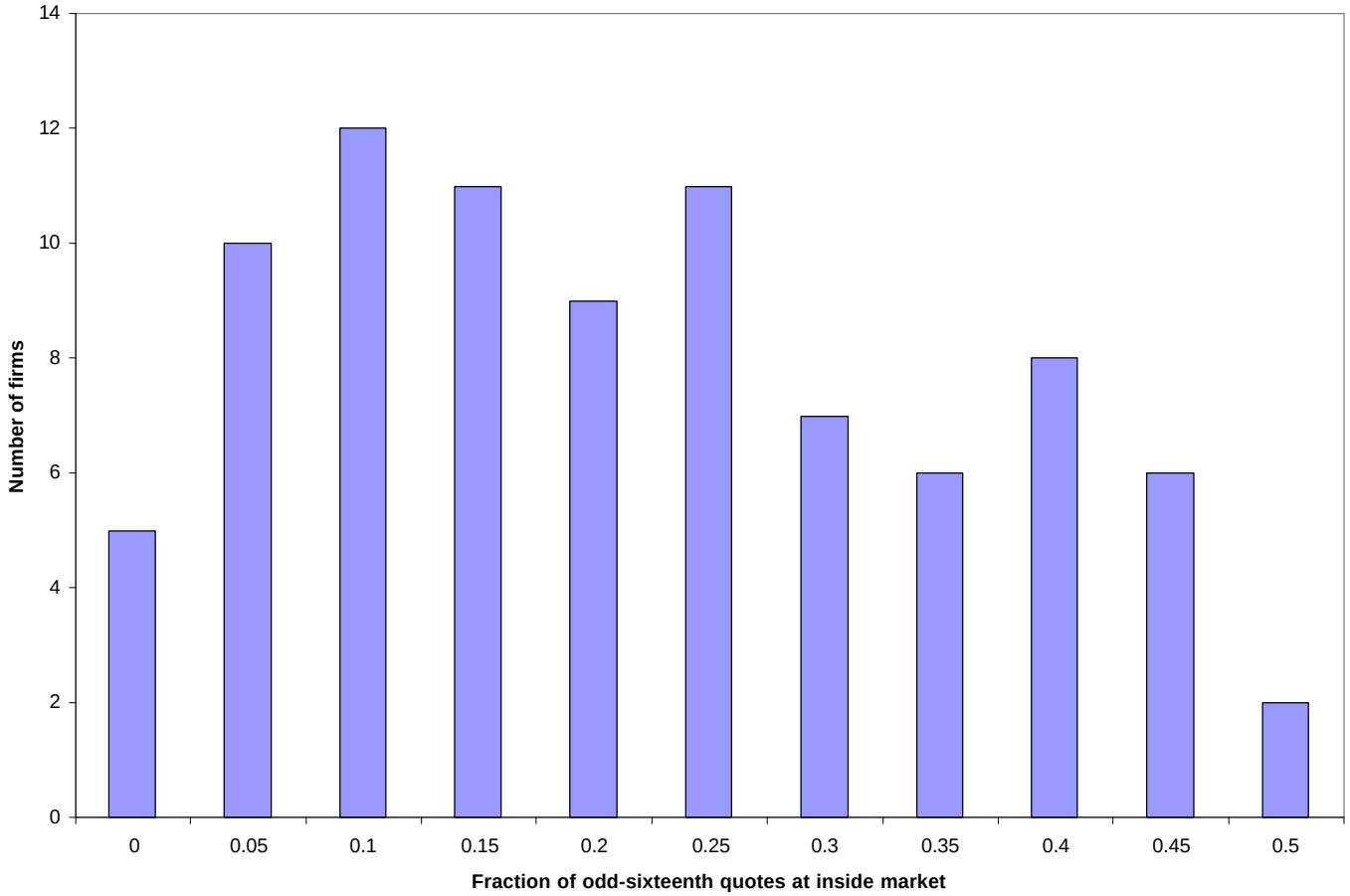

Figure 1 Frequency of odd-sixteenth quotes at the inside market.

This figure plots the proportion of inside quotes that are odd for each stock for Nasdaq stocks subject to the SEC-imposed order handling rules. The first 50 stocks were phased in on January 20, 1997, and the second 50 were phased in on February 10, 1997. Of these 100 stocks, 12 merged or ceased trading before our sample period of September 15-26, 1997. One stock traded below $10, thus was subject to a 1/32 tick size and was excluded. Therefore, the sample size is 87.