

Market Maker Quotation Behavior and Pretrade Transparency

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ABSTRACT

We examine the impact of differing levels of pretrade transparency on the quotation behavior of Nasdaq market makers. We find that market makers are more likely to quote on odd ticks, and to actively narrow the spread, when they can do so anonymously by posting limit orders on Electronic Communication Networks (ECNs). From a public policy perspective, our findings suggest that making the level of pretrade transparency on Nasdaq more opaque by allowing anonymous quotes could improve price competition and narrow spreads further.

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 investigations. The SEC investigation resulted in Nasdaq agreeing to adopt a series of order handling rule (OHR) changes, which were phased in beginning on January 20, 1997. The most significant of these changes was to include market maker “quotes” (actually limit orders) placed on Electronic Communication Networks (ECNs) in the Nasdaq National Best Bid and Offer (NBBO) quote montage.¹ ECNs such as Instinet

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¹A common misconception is that *all* ECN quotes were included in the NBBO after the OHR. In its request for comments on how it regulates exchanges, the SEC states, “These rules, however, were not intended to fully coordinate trading on alternative trading systems with public market trading. While these rules will help integrate orders on certain trading systems into the public quotation system, they only affect trading that is conducted by market makers

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. An important difference, for market makers, between placing a limit order on an ECN and posting a quote directly onto the quote montage is that ECN limit orders are displayed anonymously while a direct quote identifies the dealer. Therefore, ECN quotes can be viewed as having a lower level of pretrade transparency.

Of the four ECNs in existence at the time of our study, two were favored by day traders and two by market makers. By comparing the quotes of the two ECNs preferred by market makers with those placed directly on the Nasdaq quote montage, we are able to examine the impact of differing levels of pretrade transparency on quoting behavior.

We argue that prior to the OHR, revealing dealer identities in Nasdaq quotes may have been the mechanism that allowed other dealers to enforce implicit collusion to keep spreads wide through harassment and/or refusing to trade with offending dealers. We further argue that if dealers can post quotes anonymously, they can avoid retaliation from other dealers. Evidence suggests that Nasdaq market makers still engaged in anticompetitive practices at the time of our study.² Therefore, given that Christie and Schultz (1994) conjectured that quotes were kept wide through the avoidance of odd ticks, we predict a higher usage of odd ticks for anonymous quotes as opposed to dealer-identified quotes.

Consistent with our predictions, we find that when ECNs are *alone* at the inside spread, odd ticks are quoted about 49 percent of the time, which is close to what would be expected if all ticks were being used equally. In contrast, during those periods when the inside bid or ask is determined by a single market maker from the Nasdaq quote montage, we observe odd-tick quotes about 12 percent of the time, far less than the 50 percent that would be expected.

We find that odd-tick quotes are displayed for a much shorter period of time than even-tick quotes, providing evidence that they are quickly executed. Therefore, given that ECN quotes are anonymous and Nasdaq quotes are not, our findings suggest that Nasdaq spreads are not as narrow as they could be in a market where market makers can reveal their reservation prices without fear of retribution, for example, where quotes are made anonymously.³

and specialists; activity of other participants on alternative trading systems remains undisclosed to the public market unless the system voluntarily undertakes to disclose all of its best bid/ask prices” (*Federal Register*, June 4, 1997, p. 30493). We will show later that, other than market makers, market participants generally chose *not* have their quotes revealed to the public through the NBBO.

²See Nasdaq Press Release dated November 3, 1998, titled “NASD Regulation sanctions Olde trader for anti-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.

³Weston (2000) examines Nasdaq spreads after the order handling rules were adopted. He compares spreads on Nasdaq to three matched samples of NYSE stocks. He finds that quoted spreads for his Nasdaq sample are about 15 percent greater than spreads for their matches. He finds that effective spreads are about 25 percent larger on Nasdaq relative to the matched NYSE samples.

Barclay et al. (1999) report that spreads narrowed significantly following the OHR. The fact that ECN quotes contain more odd ticks than other quotes leads us to directly examine the contribution ECNs have made to the narrowing of quotes reported by Barclay et al.⁴ We do this by measuring the percentage of time that ECNs are alone at the inside bid or offer. We find that one or more ECNs are alone (i.e., with no market maker montage quote at the same price) at the inside (either the bid or ask) about 19 percent of the time. Therefore, ECN quotes directly reduce the inside spread about one-fifth of the time. We also find that market makers placing limit orders on ECNs have a much higher propensity to actively narrow the spread than they do when quoting directly in the Nasdaq quote montage. Lastly, we find that ECNs tend to display increased usage of odd ticks at the end of the trading day. Our findings can be interpreted as further evidence that market makers are more likely to quote aggressively if they can do so anonymously.

The remainder of this paper is organized as follows. Section I describes the institutional framework and the motives of different classes of traders. Section II describes our data and methodology. Section III presents our results, while Section IV contains concluding remarks.

I. Institutional Framework

In this section, we discuss how the OHR changed the construction of the NBBO and suggest how the changes may impact the quotation behavior of different market participants.

Prior to the OHR, Nasdaq dealers were not required to display customer limit orders in their quotes even if doing so would have narrowed the dealers' quotes. Each dealer held her own customers' limit orders. Dealers could not trade ahead of any customer limit order they held unless they offered a better price. However, since customer limit orders were not included in dealers' quotes, there may have been better prices available from limit orders held by other dealers, but best execution rules did not require a search for these orders. Best execution rules require dealers to execute incoming market orders at the "best" price available. The "best" price is defined as the NBBO.

Also prior to the OHR, the NBBO was defined as the best bid or offer from a Nasdaq dealer. Orders placed on proprietary systems such as Instinet were not incorporated. The SEC investigation that followed the Christie and Schultz (1994) study concluded that market makers routinely quoted better prices on proprietary systems, so the OHR were designed to redefine the NBBO to include these market maker orders as well as customer limit orders held by market makers. The inclusion of non-market-maker ECN quotes in the NBBO was voluntary

⁴ Although Barclay et al. (1999) examine the direct impact of ECN quote inclusion on effective spreads, they do not examine the direct impact of ECNs on quoted spreads. Although our paper is primarily concerned with the quoting behavior of market makers with and without anonymity, we can infer the impact of ECNs on quoted spreads by examining the amount of time an ECN is alone at the inside spread.

on the part of market participants. If a non-market maker chose to have his order displayed, it was made part of the Nasdaq quote montage. Otherwise, it was invisible outside the system.

It is interesting to examine the possible motives of market participants in submitting orders or quoting before and after the OHR. These motives will provide the background for our interpretation of the results of our study. The four types of market participants we examine are market makers, day traders, institutional traders, and retail traders.

We first examine the motives of Nasdaq market makers. Christie and Schultz (1994) conclude that Nasdaq market makers were implicitly colluding to keep spreads wide by avoiding odd-tick quotes.⁵ The U.S. Securities and Exchange Commission (1996) details the methods market makers would use to enforce wide spreads. They include harassment, unwillingness to trade, and narrowing the spread of a stock in which the offending market maker was a primary dealer. In order for retaliation to occur, dealers must be able to identify offending spread breakers. Under the pre-OHR Nasdaq, the only way to narrow the spread and have it made part of the NBBO was to attach one's market maker symbol. Dealers learned that the cost of the retaliation could be greater than the gain from any additional order flow resulting from the narrower (odd-tick) quote. Thus, quote competition was almost nonexistent. Prior to the OHR, quoting a narrower spread on an ECN like Instinet gave dealers anonymity, so they could avoid retaliation. However, since ECN quotes were not included in the NBBO, dealers may not have attracted any additional order flow due to best execution obligations.

Under the OHR, dealers' identities are still listed in the Nasdaq quote montage, and so if a dealer narrows the spread, she still faces the costs of retaliation, which may outweigh any profit from additional order flow. Therefore, the OHR may not increase the propensity for dealers to use odd-tick prices in the Nasdaq quote montage. However, also under the OHR, market maker orders placed on ECNs became part of the montage and, hence, of the NBBO. Since ECN orders are posted anonymously, dealers face no threat of retaliation from other dealers. So the dealer can realize the profits from any additional order flow, without facing the costs of possible retaliation.

There may be other economic reasons for dealers to seek anonymity. For example, some dealers may be known to have relationships with institutions with superior stock picking ability. Then it follows that attempts on the part of the dealer to unwind positions obtained from these institutions may have a larger price impact than if the quote could not be attributed. Thus, dealers may seek anonymity to reduce the price impact of trades designed to unwind positions. Also, since they are unwinding a position, they will tend to quote more aggressively. Similarly, certain dealers may be believed by other traders to have effective and aggressive proprietary trade desks. Forgoing anonymity would cause other

⁵ Cordella and Foucault (1996), Godek (1996), and Huang and Stoll (1996) argue that the institutional features of Nasdaq led to a lack of price competition. Dutta and Madhavan (1997) and Kandel and Marx (1997) develop theoretical models that show how these institutional features can lead to the type of implicit collusion argued by Christie and Schultz (1994).

traders to emulate the dealer's trades, making it expensive to accumulate or unwind a large position by trading in small "bites."

Therefore, we predict that under the OHR, when Nasdaq dealers narrow the spread, they have incentives to do so on an ECN rather than on the Nasdaq quote montage. Given that Christie and Schultz (1994) found that Nasdaq dealers kept spreads wide by avoiding odd-tick quotes, it then follows that under the OHR, we would expect to see an avoidance of odd-tick quotes in Nasdaq market maker quotes, but a ready acceptance of them on the ECNs used by market makers—Bloomberg Tradebook and Instinet.⁶ It also follows that spreads would narrow after the inclusion of market maker ECN orders in the NBBO. Barclay et al. (1999) show that indeed spreads did narrow.

During the period of our study Instinet and Tradebook *charged* market makers for submitting limit orders. Market makers could quote directly in the Nasdaq quote montage without cost. Institutions had access to both ECN and montage quotes and could access either for a fee. Thus the only advantage ECN orders provide market makers is anonymity, and they pay to obtain it.

Day traders are the next type of market participant we examine. Harris and Schultz (1998) examine the trading behavior of day traders prior to the OHR. They show that day traders would typically pick off stale market maker quotes using SOES and then lay off their positions by sending offers to transact with market makers via SelectNet or sometimes by hitting orders on Instinet (about 15 percent of the time). After the date of Harris and Schultz's study, but before the OHR, the Island ECN was also begun primarily as a place for day traders to lay off their trades through the placement of limit orders. Unlike Instinet, traders placing limit orders on Island were charged very modest fees—later, none at all. As Harris and Schultz illustrate, day trader profits are very sensitive to execution costs. Thus, due to the relative cost advantage of placing a limit order on Island versus Instinet and due to Instinet's reluctance to permit known day traders to use its system, Island became the ECN of choice among day traders. However, since ECNs were not part of the NBBO prior to the OHR, there is no publicly available data with which to examine their quoting behavior.

After the OHR, another ECN, Terra Nova was created. Conversations with the principals of two large day trading firms revealed that day traders used Island and Terra Nova heavily during the period of our study. Day traders seek to unwind positions as quickly as possible consistent with making a profit. Therefore, if they use limit orders rather than market orders to unwind, they want to advertise their orders by choosing to have their ECN "quotes" displayed. Therefore, we can observe day trader quoting behavior after the OHR by examining the quotes of the two ECNs favored by day traders.

⁶ Island and Terra Nova were used largely by day traders. Information obtained from Island confirmed the fact that market makers did not use Island to place quotes. During the period of our study, the only electronic connection market makers in our sample had with Island was through Nasdaq's SelectNet. SelectNet could not be used to place limit orders on Island at the time, therefore none of the market makers in our sample placed quotes on Island. The 10 market makers in our study together accounted for roughly 10 percent of Island's total volume during the period of our study.

We next consider the motives behind the quoting behavior of institutional traders before and after the OHR. Institutional traders tend to trade in size. They might be considered as having a higher probability of information-based trading than retail traders, and the mere size of their orders might be expected to move the market. Thus, the main goal of institutional traders is to execute their entire order with minimal price impact. Minimal price impact requires that the size of the order and the identity of the trader not be revealed. Neither requirement was entirely possible on market-maker-dominated Nasdaq prior to the OHR; so many institutions traded Nasdaq stocks on Instinet. Instinet allowed institutions to trade anonymously with other traders who traded in size. The other traders were generally either institutions or market makers.

After the OHR, non-market-maker orders on ECNs were included in the Nasdaq quote montage and calculation of the NBBO, but only if the order submitter requested that the order be displayed. ECNs such as Instinet and Bloomberg Tradebook gave traders the option of displaying their orders outside the system. The U.S. Securities and Exchange Commission (1998) reports that of the non-market-maker-posted ECN limit orders that could have improved the NBBO, only six percent chose to have their orders disclosed. Discussions with an official of Instinet suggest that the number of potential NBBO-improving quotes placed by non-market makers during our sample period is small. The Instinet official stated that institutions are far less comfortable setting prices than dealers. She argued that since institutions generally dealt in larger size, setting prices could have an impact on execution costs over multiple trades. In other words, setting a better price for a large quantity will most likely move prices, resulting in inferior executions for the institutions.

Therefore, after the OHR, institutions still appeared to prefer trading on proprietary systems rather than directly through Nasdaq. There are no publicly available data with which to examine the quoting behavior of institutions prior to the OHR. Further, given the low level of non-market-maker disclosed orders, institutional quoting behavior is still largely unobservable during the period of our study. Only orders displayed outside of an ECN system are captured by publicly available databases.

Finally, we consider the motives of retail limit order traders prior to the OHR. A limit order is not of much value if it is advertised to nobody or only to a very limited audience. As stated earlier, before the OHR, Nasdaq market makers were not required to display customer limit orders. Also, Instinet was designed for use by institutional traders and market makers—not retail investors. Hence, retail customers wishing to submit limit orders on Nasdaq stocks, at or better than the NBBO, would find that trades occurred at their limit price (in the case of NBBO-matching orders) or at inferior prices (in the case of NBBO-improving orders) without their limit orders executing. This phenomenon is called a “trade-through.” Consistent with the predictions of Cohen et al. (1981), this should have discouraged the submission of limit orders and caused retail customers to become market order traders—accepting market maker quotes at the NBBO. The quotation behavior of retail customers prior to the OHR is unobservable in Nasdaq quotes, but was probably nearly nonexistent. The extent that retail customers

contributed to the (albeit low) level of odd-tick transactions reported by Christie and Schultz (1994) cannot therefore be determined.

The OHR requires that customer limit orders (submitted to a dealer) that improve on a dealer's quote or add to the size of the quote be executed immediately by the dealer, be made part of the dealer's quote, or be posted on an ECN.⁷ If dealers provide the contra side to customer limit orders, then there will be no impact on quotes from these orders. Otherwise, given that during the period of our study ECNs *charged* market makers for submitting limit orders, rational expectations suggest that market makers would seek to maximize revenue and display customer limit orders as part of their quote. If however, displaying customer limit orders in market maker quotes leads to narrower spreads and possible retribution from other dealers, a market maker may pay the fee to list the limit order on an ECN in an attempt to avoid economic loss from retribution.⁸ We would thus expect market makers to send quote-narrowing limit orders to ECNs to employ the anonymity necessary to avoid retribution. The predicted quoting behavior of customer limit orders submitted to dealers is then identical to that of dealers' quotes. We would expect a larger percentage of odd-tick quotes on ECNs in comparison to Nasdaq market maker quotes as well as a narrowing of spreads.

Therefore, we conclude that in the post-OHR world, profit-maximizing market makers have incentives to send large customer limit orders to and unwind positions on anonymous ECNs. Further, the high level of pretrade transparency on Nasdaq will keep dealer-identified quotes wider than they would be otherwise. The result is a system where quoted spreads are occasionally narrowed, leading to a reduction in average quoted spreads. The average quoted spread is not, however, as narrow as it could be if all quotes were anonymous. Evidence supporting our contention that Nasdaq spreads could narrow further is provided by Weston (2000).

Not all retail orders are submitted through dealers. Some are submitted to order entry brokers who have different order routing methods. If a retail limit order is routed to a dealer, then the above scenario holds. However, some order entry brokers, such as Datek Online, automatically send customer limit orders for Nasdaq stocks to an ECN (Island in the case of Datek, Terra Nova in the case of

⁷There is a serious question of whether market makers actually have conformed to this rule. Schroeder (2000, p. C7) reports that SEC Chairman Arthur Levitt said that "the SEC has found an alarming failure by broker-dealers to display investors' limit orders and is conducting a market-wide review to determine the scope of the problem." Such a failure to display is not surprising considering the fact that customer limit orders (a) compete with dealers' own-account quotes and (b) can be a source of trading profit to the dealer if they are concealed and executed if and when the counterpart quote matches the limit price (making the limit order effectively a market order). Accordingly, market makers' customers may "learn" not to use limit orders, restricting their use materially. Since the date of our data collection, online brokerages offering customers direct access to ECNs to post their limit orders have proliferated, but during the study period, essentially only day traders had such access.

⁸This could also explain the economic rationale for the "Agency Quote" proposal (SR-NASD-99-09), which would give market makers a separate, identifiable market maker ID in the quote montage solely for customer limit orders; presumably there would be no retribution for customer spread-narrowing orders.

others). Since retail customers have no incentive to keep spreads wide, we would again expect that customer limit orders displayed on Island and Terra Nova will exhibit a larger percentage of odd-tick prices than in the Nasdaq quote montage.

The differing motives of the four classes of traders listed above may lead to different quoting behaviors. We do not have access to order data, so we cannot directly identify the class of trader posting a quote. However, we illustrate above that the classes have preferred trading venues. Therefore, we can use the trading venue to infer the identity of traders and thus examine any differences in quoting behaviors. To summarize, during the period of our study, there were four ECNs in existence in addition to the Nasdaq quote montage. Two of the ECNs (Island and Terra Nova) were used primarily by day traders and may have had some retail limit orders. The other two ECNs (Bloomberg Tradebook and Instinet) were used primarily by market makers to post principal or agency (retail) limit orders and by institutions. Finally, the Nasdaq quote montage was used by market makers to post quotes, which may have been principal or agency (retail).

Retail limit orders were then present to some degree on each ECN as well as the Nasdaq quote montage. Institutions preferred two of the ECNs, but also largely chose not to have their quotes displayed outside of the ECN. Day traders preferred two ECNs and market makers the remaining two. Recall that ECNs provide anonymity, while the Nasdaq quote montage does not. Thus, by comparing the quotation patterns of market-maker-preferred ECNs with that of the Nasdaq quote montage, we can observe the impact that anonymity has on market maker quoting behavior. We can also compare this with day trader quoting behavior by including an analysis of the two ECNs preferred by day traders.

II. Data and Methodology

Due to the amount of data involved, we limit our study to the 10-day period September 15–26, 1997. The minimum tick size during this period is $1/16$. 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.

The NQDS feed is used to calculate the NBBO. Thus, 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. One limitation of any quote data from the period of our study is that if an ECN has a tick size smaller than $1/16$, then buy (sell) orders posted at prices that are not an integer multiple of $1/16$ are rounded to the 16th below (above) the actual limit price. 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. (1999). Specifically, we include the 50 stocks which NASD included in the

OHR pilot program (begun January 20, 1997) that were subject to the Actual Size Rule ("First 50"), as well as the 50 stocks included in the second phase of the OHR pilot program (begun February 10, 1997), but which continued to have 1,000 share minimum proprietary quote sizes ("Second 50"). Data for some of the original 100 stocks were no longer available for our study period due to mergers, moves to other trading venues, and so forth. This reduced our sample to 44 stocks from the First 50 and 42 to 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-tick 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 OHR 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.

Recall that we predict that market maker orders represented as anonymous ECN quotes should exhibit a higher frequency of odd tick usage than market maker quotes. Accordingly, we disaggregate our data and examine the quotes posted by ECNs and a group of market makers. During the time of our study, there were four ECNs posting quotes: Bloomberg Trade Book, Instinet, Island, and Terra Nova. Discussions with the principals of two large day trading firms revealed that, during the time of our study, Island and Terra Nova were largely used by day traders, while Bloomberg Tradebook and Instinet were used primarily by market makers and institutions.

Also recall that according to the SEC, around the time of our sample period, non-market-maker orders on Instinet that improved on the NBBO were not revealed in the NBBO 94 percent of the time. Further, Island and Terra Nova had not yet developed a large retail customer base. Thus, the quotes from Instinet and Bloomberg Tradebook can be considered largely market maker orders and those of Island and Terra Nova as day trader orders. Accordingly, we further disaggregate the ECN data into two groups, which we call DT ECNs (Island and Terra Nova) and MM ECNs (Instinet and Bloomberg Tradebook). We define our market maker group as the 10 Nasdaq market makers making markets in the largest number of stocks in our sample on the first day, September 15, 1997.

For each group, we calculate the time-weighted average of odd tick 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 each group at the inside is examined as well. We sepa-

rate cases where a member of a group is at the NBBO with others from cases where the entity is alone.

Chan, Christie, and Schultz (1995) and Barclay et al. (1999) 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 also disaggregate our data by hour of the trading day.

During the period of our study, non-market-maker orders placed on ECNs were not required to be part of the NBBO. Therefore, there may be NBBO-improving quotes that we cannot observe. If these invisible quotes tend to be on an odd tick, then an increased incidence of odd-tick transactions may merely reflect transactions at these invisible quotes. Therefore, comparing the percentage of odd-tick trades to odd-tick quotes to determine if odd-tick quotes are quickly eliminated, as was done in Christie and Schultz (1994), would be problematic. Instead, we directly examine the length of time quotes at the inside alone last, on average, for each group in our study.

The contribution of ECNs to the narrowing of spreads reported by Barclay et al. (1999) is measured by calculating the proportion of time ECNs are alone at the inside. We separately measure the average proportion of the time that one, two, three, four, or any number (one to four) of ECNs are alone at the inside.

ECNs or market makers can be alone at an inside bid or ask by either actively improving the current quote, or by passively not updating their quote when others move away from it. Actively going to the inside alone is consistent with the notion that market makers will narrow the spread to unwind a large position. Recall that market makers placing anonymous limit orders on ECNs probably generate the majority of quotes we observe from certain ECNs. We predict that market makers will have a higher propensity to quote competitively if they can do so anonymously. Therefore, we expect market makers to actively go inside alone on ECNs more frequently than with regular Nasdaq market maker quotes.

To test this hypothesis, we identify all NBBO quotes where only one entity (ECN or market maker) is on the bid or ask. We then compare the inside alone entity's quote to its previous quote. If the entity achieved inside alone status by actively improving on the previous NBBO quote, then we deem that as "active" narrowing. If however, the entity was left alone at the inside because other entities worsened their quotes away from the inside, we deem that as "passive." We then calculate the percentage of instances in which alone inside was actively achieved for each entity. To examine whether the propensity to actively go alone inside differs for odd versus even ticks, we disaggregate the data according to what type of tick the alone inside quote is on.

Related to the price of a quote is the number of shares the quote represents. Accordingly, we examine the pattern of quoted size associated with odd- and even-tick quotes for each group. We examine overall as well as intertemporal patterns.

III. Results

A. Odd-tick Quotation Behavior of Market Makers and ECNs

We first disaggregate the data into two types of ECNs (denoted DT for day trader preferred and MM for market maker preferred) as well as quotes placed directly on the Nasdaq montage (denoted Montage), and then 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 percent for each group.

Panel A of Table I summarizes our results averaged over the day. Overall, we find that DT ECNs quote in odd ticks 17.6 percent of the time. In contrast, MM ECNs quote odd ticks marginally more than Montage quotes (7.6 percent vs. 6.7 percent). We perform both parametric and nonparametric significance tests (not reported). We take two differences: (1) the difference between the sample average frequency of odd ticks and 50 percent, and (2) the difference between the odd-tick quote frequency of each group. In each case, we perform three significance tests: a Student *t* parametric test and two nonparametric 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 significant.

The frequency of odd-tick 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 ticks for reasons explained by the “clustering” hypothesis (people take the easy course of using “round” numbers except when a material difference in transaction probability forces them to quote more competitively). Looking at the frequency of odd ticks conditional on the quoter being at the inside (Table I, Panel A, columns 5-7) we see that, on average, Montage quotes are on odd ticks 11.5 percent of the time that they are at the inside, clearly a higher frequency than for quotes at all prices, but still significantly below 50 percent. By contrast, the MM ECN group quotes odd ticks over 35 percent of the time that they are on the inside; this proportion is significantly higher than that of Montage quotes or of DT ECNs. Again, the differences between groups and from the 50 percent odd “expectation” are statistically significant. Our findings are consistent with our predictions that the propensity of market makers to freely use all ticks is related to the degree of anonymity they receive.

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 Montage and ECN quoting behavior is most striking. Montage quotes are on odd ticks only 11.7 percent of the time that they are alone on the inside, whereas both DT and MM ECNs quote odd ticks over 49 percent of the time that they are alone inside. Thus, both day traders and market makers use odd ticks in about the same proportion as even ticks, when quoting alone on an ECN. Market makers still tend to avoid odd ticks in the Nasdaq quote montage.

Further evidence regarding market maker propensities to quote odd ticks without anonymity 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 Montage odd-tick quotes relative to Second 40 stocks for every group. For example, the sample average frequency of odd-tick quotes at the inside for Montage quotes is 6.6 percent for First 40 stocks and rises to 9.7 percent 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 for the First 40.⁹ Quoting smaller sizes can result in a smaller inventory buildup for market makers. 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 day traders" and, hence, reduces the aggressiveness with which they have to lay off these positions.

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 period by period over the trading day. Panel B of Table I shows quotation behavior by hour for the two-week period studied. We separate the last hour of trading into consecutive periods. In general, the frequency of odd tick for ECNs and Montage quotes, whether at all prices, at the inside, or inside alone, rises steadily over the trading day. For example, only 8.9 percent of Montage inside quotes are on odd ticks in the 9:30 to 10:00 period, while 13.8 percent of inside quotes are on odd ticks during the 3:45 to 4:00 period. The findings here are consistent with Chan et al. (1995) and Barclay et al.'s (1999) finding that spreads tighten over the day.

The increase in price competition, as the day matures, is consistent with the idea that market makers want to "go home flat." Day traders seek to reverse their positions as soon as they acquire them (see Harris and Schultz (1998)), so they should not exhibit the same temporal increase in price competition as market makers. Examining the intertemporal quoting patterns for DT and MM ECNs at the NBBO shows that this is indeed true. MM ECNs exhibit an increasing usage of odd ticks through the day, while DT ECNs show a much flatter pattern. In addition, the fact that both market-maker-preferred ECN and Montage odd-tick quotes increase as the day progresses suggests that market makers *do* use their quotes, at least to a modest extent, to 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-tick montage quotes as

⁹ Barclay et al. (1999) do report in their 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 versus the Second 40. However, our data suggest that the First 10 appear to have a *higher* propensity for odd-16th market maker quotes, so it is likely that the pre-January 20 results were caused by a 40 versus 40 difference.

Table I
Odd-tick Quotation Frequencies

This table reports the sample average percentage of the time that quotes occur on odd ticks. The data cover the period September 15–26, 1997, and include all quotes made in the First 50 and Second 50 stocks by four ECNs and the 10 largest market makers. Quote data are separated into day-trader-dominated (DT) and market-maker-dominated (MM) ECNs. Quotes placed directly on the Nasdaq quote montage are separately listed under the heading Montage. Panel A reports odd-tick 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 period-by-period averages over the trading day. Of the original 100 stocks, 12 merged or ceased trading before our study and 1 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		
	DT ECNs	MM ECNs	Montage	DT ECNs	MM ECNs	Montage	DT ECNs	MM ECNs	Montage
Panel A: Average over the Day									
Overall	17.6%	7.6%	6.7%	29.6%	36.2%	11.5%	49.4%	49.1%	11.7%
First 10	40.6%	29.9%	18.4%	42.4%	46.7%	27.2%	65.0%	69.7%	15.4%
First 40	12.2%	3.4%	4.0%	21.9%	32.3%	6.6%	41.8%	42.8%	10.1%
Second 10	25.0%	12.7%	12.5%	36.6%	39.4%	19.8%	63.3%	59.5%	14.6%
Second 40	16.2%	5.8%	5.7%	27.8%	36.5%	9.7%	49.9%	52.9%	12.2%
Panel B: Average by Time of Day									
9:30–10:00	10.7%	5.4%	5.4%	29.3%	32.6%	8.9%	50.3%	45.7%	10.6%
10:00–11:00	17.5%	7.6%	6.1%	27.5%	34.4%	10.2%	47.7%	46.2%	10.7%
11:00–12:00	19.6%	8.4%	6.7%	29.1%	36.4%	11.4%	48.5%	51.3%	10.7%
12:00–1:00	19.8%	8.5%	7.0%	30.1%	37.3%	12.6%	50.9%	50.6%	11.5%
1:00–2:00	19.6%	8.6%	6.9%	29.9%	36.1%	11.8%	49.9%	48.7%	12.6%
2:00–3:00	19.7%	8.6%	7.2%	32.0%	37.9%	12.0%	50.7%	48.1%	13.2%
3:00–3:45	18.5%	7.7%	7.2%	31.9%	37.9%	12.8%	54.0%	50.2%	12.64%
3:45–4:00	14.8%	5.9%	7.6%	30.9%	38.4%	13.8%	53.5%	51.1%	12.99%

the day progresses, other than that this results from more aggressive layoff activity.

As an interesting aside, we examine the montage-quoted size of the market makers in our sample for stocks not subject to the ASR. If dealers only quote the minimum 1,000 share size, then for these stocks, quoted sizes greater than 1,000 shares may represent customer limit orders. We may then obtain a sense of the contribution of customer limit orders to montage quotes. However, our analysis must be tempered by reports in the popular press that dealers are not including customer limit orders in their quotes. We find that, for stocks in the Second 10 and Second 40, when dealers quote at the inside, quoted size is over 1,000 about 14 percent of the time.¹⁰ There is significant variation in the percentage of quotes

¹⁰ Complete results are available from the authors.

over 1,000 across dealer firms. For example, one dealer never quotes over 1,000 shares, while others quote large size over 35 percent of the time they are at the inside. Finally, we find that large size inside montage quotes are on an odd tick about 27 percent and 18 percent of the time for stocks in the Second 10 and Second 40, respectively. The percentage of odd price quotes for the larger quoted sizes is greater than the odd quote montage percentage but less than the MM ECN percentage, suggesting that customer limit orders use odd prices more often than dealers quoting in the nonanonymous montage. However, without order data, we cannot determine whether the large size quotes are from customer limit orders or represent dealer quoted sizes.

We next calculate the number of seconds a quote is displayed and then average across stocks in each sample as well as for each group. We disaggregate by odd and even-tick quotes and calculate the ratio of quote duration for odd versus even quotes. If odd-tick quotes are neither more nor less competitive than even tick quotes, we should see no difference in the length each type is displayed and hence the ratio should be near one.

Table II contains the results. Examining the ratios reveals that all but two ratios are less than 67 percent, suggesting that odd-tick quotes last less than two-thirds of the time that even-tick quotes are displayed. This provides evidence that odd-tick quotes represent "better" prices and are quickly taken out.

Interestingly, montage inside-alone quotes generally have shorter durations than those on ECNs. This may be due to Nasdaq's excess spread rule that was still in effect at the time of this study. The excess spread rule required market makers to post spreads that were no more than 150 percent of the average of all market maker spreads in a security. Prior to 1997, Nasdaq workstations were programmed to warn market makers of potential quoted spread violations. During

Table II
Duration of Quote at Inside Alone

This table compares the average time (in seconds) that quotes are outstanding. Data cover the 10-trading-day period September 15–26, 1997, and include all quotes made in First 50 and Second 50 stocks by four ECNs and the 10 largest market makers. Quote data are separated into day-trader-dominated (DT) and market-maker-dominated (MM) ECNs. Quotes placed directly on the Nasdaq quote montage are separately listed under the heading Montage. Data are disaggregated by stock group (First 10, ..., Second 40). Odd and even quote durations as well as the odd to even ratio are calculated.

Group	DT ECNs			MM ECNs			Montage		
	Odd-tick Quotes	Even-ticks Quotes	Ratio	Odd-tick Quotes	Even-ticks Quotes	Ratio	Odd-tick Quotes	Even-ticks Quote	Ratio
Overall	700	1,207	0.58	1,095	1,685	0.65	486	1,156	0.42
First 10	532	847	0.63	48	136	0.35	98	156	0.63
First 40	856	1,347	0.64	1,487	2,345	0.63	605	1,561	0.39
Second 10	683	1,066	0.64	209	235	0.89	27	487	0.55
Second 40	672	1,264	0.53	1,374	1,633	0.84	607	1,121	0.54

January 1997, Nasdaq removed the automatic notification of potential violations requiring market makers to actively monitor spreads for each stock. This lack of notification may have led market makers to exhibit herding behavior on quotes, since the penalty for violating the excess spread rule was exclusion from doing business in that security for 20 days. Thus, the duration of inside-alone quotes on the montage would be expected to be shorter due to herding behavior.

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 OHR, 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 OHR 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 percent of the time. However, once the tick size fell to 1/16, 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 first post-16ths statistics (for the period from the June 2, 1997, move to 16ths to August 31, 1997) show ECNs alone about 14 to 18 percent of the time for First 50 stocks.¹¹ NASD statistics for all 2,900 stocks then subject to the OHR show ECNs alone inside 10.1 percent of the time (for a 15-day period following September 15, 1997).

The results for our sample of stocks are reported in Table III. We find that overall, ECNs are alone at the inside 19 percent of the time (Panel A). As noted above, this helps explain why the OHR reduced spreads so much. Table III also 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 OHR 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 III shows that 17.9 percent of the time there is only one ECN alone at the inside. Instinet is on the inside the most (15.1 percent of the time), followed by Island (1.8 percent), Bloomberg Trade Book (0.8 percent) and Terra Nova (0.2 percent).

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 percent of the time) than on the bid (17.9 percent of the time) during this period. This result holds for both DT and MM ECNs.

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

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

Table III
ECNs Alone at Inside Spread

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 four 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, and 4. The overall data are also disaggregated by side (bid vs. ask). Panel B contains averages period-by-period 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, and 1 was subject to a 1/32-tick size. Therefore, the sample size is 87.

Percentage of Time ECN Is Alone at Inside											
Group	Side of Quote	N	By Number of ECNs Alone at Inside				Overall	Bloomberg Trade Book	By ECN		
			1	2	3	4			Instinet	Island	Terra Nova
Panel A: Average over the Day											
Overall	Either	1,736	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%
Panel B: Average by Time of Day											
9:30–10:00	Either	1,736	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%
3:00–3:45			19.9%	1.2%	0.050%	0.0008%	21.1%	1.3%	17.8%	1.9%	0.2%
3:45–4:00			18.9%	1.2%	0.050%	0.0008%	20.1%	0.5%	15.3%	1.6%	0.2%

market makers. As Figure 5 in Barclay et al. (1999) shows, Nasdaq spreads are widest as price discovery begins just after the market opens at 9:30 a.m. The spread drops precipitously up to 10:00 a.m., declines slowly during the day until about 3:30 p.m., and then drops precipitously again during the last half-hour of trading. Such behavior is consistent with the common presumption that market makers do not like to hold positions overnight. 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.

The findings reported in this section provide further evidence that market makers will quote more aggressively if they can do so anonymously. 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 our predictions.

The data we present here may 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 1/16, 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.

C. How ECNs and Market Makers Got to the Inside Alone

We have suggested that market makers have a higher propensity to be competitive if they can do so anonymously, that is, by placing a limit order on an ECN. It then follows that market makers will prefer to actively narrow standing quotes by placing orders on an ECN rather than quoting in the Montage.

Table IV examines the percentage of inside alone instances that are achieved actively for each ECN group as well as for the Montage. Consistent with our predictions, we find that overall, limit orders on MM ECNs are more likely to actively narrow the spread (13.8 percent) compared to Montage quotes (12.1 percent). The difference is statistically significant at the 1 percent level. However, day traders appear to be more willing to actively narrow the spread than are market makers. This is evidenced by the fact that DT ECNs actively narrow the spread 23 percent of the time.

This relationship between DT ECNs, MM ECNs, and Montage quotes holds for all but one stock subgroup or tick type. The results of Table IV provide strong support for our prediction that Nasdaq market makers will be more competitive if they can post quotes anonymously. It also suggests that day traders have contributed to the narrowing of spreads on Nasdaq.

We expect that a market maker that has just acquired a large position would tend to be more price competitive. Given the evidence presented thus far, we would expect that when quoting on an ECN (i.e., more competitively) a market

Table IV
How Quoters Got to the Inside Alone

This table examines how quoters got to the inside alone. Data cover the 10-trading-day period September 15–26, 1997, and include all quotes made in First 50 and Second 50 stocks by four ECNs and the 10 largest market makers. Quote data are separated into day-trader-dominated (DT) and market-maker-dominated (MM) ECNs. Quotes placed directly on the Nasdaq quote montage are separately listed under the heading Montage. Quoters can be alone at the inside either by improving on an existing NBBO quote (active) or not updating their quote when others move away from the inside (passive). We report the percentage of inside-alone quotes that represent active narrowing. Averages are computed over the trading day. Of the original 100 stocks, 12 merged or ceased trading before our study, and 1 was subject to a 1/32-tick size. Therefore, the sample size is 87.

Group	Frequency of Time That a Market Maker or ECN Actively Narrowed the Spread (%)								
	All Ticks			Even Ticks			Odd Ticks		
	DT ECNs	MM ECNs	Montage	DT ECNs	MM ECNs	Montage	DT ECNs	MM ECNs	Montage
Overall	23.0%	13.8%	12.1%	30.5%	19.4%	14.0%	16.9%	10.2%	7.3%
First 10	11.01%	9.3%	5.6%	16.4%	14.3%	7.2%	7.6%	6.4%	3.3%
First 40	34.6%	16.9%	19.9%	40.8%	19.8%	20.8%	28.1%	14.2%	16.6%
Second 10	23.7%	17.2%	10.8%	31.9%	25.2%	12.0%	17.3%	12.4%	7.3%
Second 40	28.4%	17.2%	14.9%	35.5%	22.3%	16.1%	21.9%	13.5%	10.9%

maker will quote more size if quoting on an odd tick than on an even tick. Therefore, we calculate the depth at the inside for each ECN group as well as for the Montage. The results given in Table V support our predictions. Whether at the NBBO, or at the inside alone, MM ECNs tend to quote a significantly larger amount of depth on an odd tick than on an even tick. The difference between depths on odd and even ticks for DT ECNs and Montage quotes is much smaller than for MM ECNs. This difference holds true for all subgroups. This provides further evidence that market makers will quote more aggressively if they can do so anonymously.

IV. Conclusion

In this paper, we examine the impact of differing levels of pretrade transparency on the quotation behavior of Nasdaq market makers. We argue that prior to the OHR, revealing dealer identities in Nasdaq quotes may have been the mechanism that allowed other dealers to enforce implicit collusion to keep spreads wide through harassment and/or refusing to trade with offending dealers. We further argue that if dealers can post quotes anonymously, they will quote more aggressively. We find that when ECNs are *alone* at the inside spread, odd ticks are quoted about 49 percent of the time, which is consistent with our predictions. In contrast, during those periods when the inside bid or ask is determined by a single market maker from the Nasdaq quote montage, we observe odd ticks only about 12 percent of the time.

Table V
Time-weighted Average Quoted Size

This table reports time-weighted average quoted size. Data cover the 10-trading-day period September 15–26, 1997, and include all quotes made in First 50 and Second 50 stocks by four ECNs and the 10 largest market makers. Quote data are separated into day-trader-dominated (DT) and market-maker-dominated (MM) ECNs. Quotes placed directly on the Nasdaq quote montage are separately listed under the heading Montage. For each group we separately report the depth for odd- and even-tick quotes as well as the difference. Panels A and B report the average at the NBBO, and when at the inside alone, respectively. Of the original 100 stocks, 12 merged or ceased trading before our study, and 1 was subject to a 1/32-tick size. Therefore, the sample size is 87.

	DT ECNs			MM ECNs			Montage		
	Odd-tick Quotes	Even-ticks Quotes	Difference	Odd-tick Quotes	Even-ticks Quotes	Difference	Odd-tick Quotes	Even-ticks Quote	Difference
Panel A: At NBBO—Over the Day									
Overall	766	799	– 33	1,690	1,454	235	997	970	27
First 10	714	722	– 8	2,511	2,259	252	934	946	– 12
First 40	822	823	– 1	1,267	1,145	122	1,000	928	72
Second 10	747	764	– 17	2,593	2,280	314	1,003	976	27
Second 40	808	841	– 33	1,648	1,492	157	1,043	1,014	29
Panel B: At Inside Alone—Over the Day									
Overall	722	693	29	1,405	1,166	239	1,029	960	68
First 10	586	586	0	1,990	1,950	40	923	915	8
First 40	794	694	100	1,220	1,014	206	981	920	61
Second 10	697	703	– 6	1,563	1,389	175	956	930	25
Second 40	803	780	24	1,516	1,312	204	1,114	1,021	93

We also find that odd-tick quotes are displayed for a much shorter period of time, providing evidence that they represent more competitive prices, and hence are more quickly executed. By measuring the percentage of time that ECNs are alone at the inside bid or offer, we are able to examine the contribution ECN quotes make to the observed post-OHR spread narrowing. We find that one or more ECNs are alone (i.e., with no market maker montage quote at the same price) at the inside (either the bid or ask) about 19 percent of the time. Therefore, ECN quotes directly reduce the inside spread about one-fifth of the time. We also find that market makers placing limit orders on ECNs have a much higher propensity to actively narrow the spread than they do when quoting directly in the Nasdaq quote montage. Our findings can be interpreted as further evidence that market makers are more likely to quote aggressively if they can do so anonymously.

Our findings suggest that the relatively high level of pretrade transparency on Nasdaq is an impediment to competitive markets. Including anonymous ECNs in the calculation of the NBBO removed part of the impediment and narrower spreads followed. Making the level of pretrade transparency on Nasdaq more opaque by allowing anonymous quotes could further improve price competition and narrow spreads further.

REFERENCES

- Barclay, Michael J., William G. Christie, Jeffrey H. Harris, Eugene Kandel, and Paul H. Schultz, 1999, The effects of market reform on the trading costs and depths of Nasdaq Stocks, *Journal of Finance* 54, 1–34.
- Chan, K.C., William G. Christie, and Paul H. Schultz, 1995, Market structure and the intraday pattern of bid-ask spreads for Nasdaq securities. *Journal of Business* 68, 35–60.
- Christie, William G., and Paul H. Schultz, 1994, Why do Nasdaq market makers avoid odd-eighth quotes? *Journal of Finance* 49, 1813–1840.
- Cohen, Kalman J., Steven Maier, Robert A. Schwartz, and David K. Whitcomb, 1981, Transaction costs, order placement strategy and the existence of the bid-ask spread. *Journal of Political Economy* 89, 287–305.
- Cordella, Tito, and Thierry Foucault, 1996, Minimum price variations, time priority, and quote dynamics. Working paper, Universitat Pompeu Fabra.
- Dutta, Prajit K., and Ananth Madhavan, 1997, Competition and collusion in dealer markets, *Journal of Finance* 52, 245–276.
- Godek, Paul, 1996, Why Nasdaq market makers avoid odd eighth quotes. *Journal of Financial Economics* 41, 465–474.
- Harris, Jeffrey H., and Paul Schultz, 1998, The trading profits of SOES bandits, *Journal of Financial Economics* 50, 39–62.
- Huang, Roger, and Hans Stoll, 1996, Dealer versus auction markets: A paired comparison of execution costs on Nasdaq and the NYSE, *Journal of Financial Economics* (July), 313–358.
- Kandel, Eugene, and Leslie M. Marx, 1997, Nasdaq market structure and spread patterns, *Journal of Financial Economics* 45, 61–89.
- National Association of Securities Dealers, 1997, Effects of the removal of minimum sizes for proprietary quotes in the Nasdaq Stock Market, Inc., June 3.
- Schroeder, Michael 2000, SEC studies brokers' failure to disclose stock limit orders, *Wall Street Journal*, March 17, p. C7.
- Stuart, Alan, and Maurice G. Kendall, 1961, *The Advanced Theory of Statistics*, Volume 2 (Hafner Publishing Co., New York).

- U.S. Securities and Exchange Commission, 1996, Report pursuant to Section 21(a) of the Securities Exchange Act of 1934 regarding the NASD and the Nasdaq Stock Market, Washington, DC.
- U.S. Securities and Exchange Commission, 1997, Concept release; request for comments; 17 CFR Part 240, Release No. 34-38672; International Series Release No. 15-1085; File No. 57-16-97 Regulation of Exchanges, Washington, D.C., 30485–30535.
- U.S. Securities and Exchange Commission, 1998, Release No. 34-39884, Regulation of Exchanges and Alternative Trading Systems, Washington, DC.
- Weston, James P., 2000, Competition on the Nasdaq and the impact of recent market reforms, *Journal of Finance* 55, 2565–2598.
- Wolfe, Douglas A., and Myles Hollander, 1973, *Nonparametric Statistical Methods* (John Wiley & Sons, New York).