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PRICE AND QUANTITY QUOTES ON NASDAQ: A STUDY OF DEALER QUOTATION BEHAVIOR

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Abstract

We show that the majority of quotes posted by NASDAQ dealers are noncompetitive and only 19.5% (18.4%) of bid (ask) quotes are at the inside. The percentage of dealer quotes that are at the inside is higher for stocks with wider spreads, fewer market makers, and more frequent trading, and lower for stocks with larger trade sizes and higher return volatility. These results support our conjecture that dealers have greater incentives to be at the inside for stocks with larger market-making revenues and smaller costs. Dealers post large depths when their quotes are at the inside and frequently quote the minimum required depth when they are not at the inside. The latter quotation behavior leads to the negative intertemporal correlation between dealer spread and depth.

JEL Classification: G14

I. Introduction

Market makers post both the price (i.e., the bid and ask price) and the quantity (i.e., the bid and ask depth) of shares they are willing to trade. However, most previous studies of market microstructure focus only on the price quotes of market makers. To the extent that market makers have discretion on both variables and manage them strategically, the analysis of price quotes in isolation of depth quotes is likely to show only an incomplete picture of dealer behavior. In this article we analyze how NASDAQ dealers use both dimensions of the quote as they provide liquidity to the market. We perform both the cross-sectional and intertemporal

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analyses of dealer quotation behavior with a focus on how they establish price and quantity quotes interdependently. Our analyses shed light on how NASDAQ dealers maximize market-making profits through their selective presence at the inside market.

Lee, Mucklow, and Ready (1993) examine intraday variation in the spread and depth of stocks traded on the New York Stock Exchange (NYSE) and find that wider spreads are accompanied by smaller depths. They also show that spreads widen and depths drop in advance of the Broad Tape announcement of quarterly earnings and that the magnitude of liquidity changes is positively related to subsequent price reactions. The authors interpret this result as evidence that information asymmetry risk increases immediately before anticipated news events. Harris (1994) analyzes the effect of the minimum price variation on NYSE specialist quotes and finds that the minimum price variation affects depths when it is larger than the spread that dealers would otherwise quote (i.e., when the minimum price variation is a binding constraint).

Ye (1995) develops a model of dealer quotation strategy and suggests that it is optimal for market makers to increase spreads and decrease depths as the probability of informed trading increases. Kavajecz (1996) suggests that NYSE specialists use depths as a strategic variable to reduce the risk associated with information events. Kavajecz (1999) shows that both specialists and limit-order traders post smaller depths around earnings announcements and thereby reduce their exposure to adverse-selection costs. Goldstein and Kavajecz (2000) examine the effect of reducing the minimum tick size on both spreads and depths for NYSE stocks. They find that both quoted spreads and depths declined after the NYSE's tick size changed from eighths to sixteenths. Kavajecz and Odders-White (2001) show that NYSE specialists revise their price schedules according to changes in the limit-order book, transactions, and overall trading activity.

Although the results of these studies underscore the importance of recognizing both the price and quantity dimensions of dealer quotes, there are still many unanswered questions about how market makers use the price and depth quotes. Previous studies of the spread-depth interaction focus mostly on specialist quotes on the NYSE. There is only limited evidence on NASDAQ dealers' price and depth quote decisions. In this article we provide evidence regarding the interactive nature of price and quantity quotes on NASDAQ.

NASDAQ operates under the multiple-dealer system whereas the NYSE operates under the specialist system. There is only one specialist for each NYSE stock and the specialist is required to maintain a market presence by posting the bid and ask quotes at all times if no one else is willing to do so.[1] In contrast, there are multiple dealers for NASDAQ issues, and although dealers are required to quote on

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[1]Although each NYSE stock has only one specialist, the specialist faces competition from limit-order traders, floor trades, regional exchanges, and NASDAQ.

both sides, evidence suggests that they tend to post competitive quotes (i.e., inside market quotes) on only one side of the quote. The extant literature does not provide evidence regarding the exact nature of NASDAQ dealers' selective presence at the inside market. For example, we do not know whether dealers post the inside market quotes more frequently for certain stocks than others. Furthermore, it is unclear whether dealers' quantity quotes are related to price quotes. We believe that empirical evidence regarding these issues helps us better understand the market-making behavior of NASDAQ dealers and thereby sheds further light on the effect of market structure on dealer quotation behavior.

Our empirical results indicate that there is wide cross-sectional variation in the percentage of quotes (time) at the inside market. The percentage of dealer quotes (time) at the inside market is higher for stocks with wider spreads, fewer market makers, and more frequent trading, and lower for stocks with larger trade sizes and greater return volatility. These results support our conjecture that NASDAQ dealers have greater incentives to be at the inside market for stocks with larger market-making revenues and smaller costs. We find that NASDAQ dealers tend to quote large depths when they post the inside market quotes. In contrast, dealers frequently quote the minimum required depth (100 shares) when they post noncompetitive price quotes. We attribute these results to dealers' discretionary depth quotes that are conditional on limit orders and the NASDAQ rule that dealers must make a two-sided continuous market. Finally, we show that the previously described behavior leads to the negative intertemporal correlation between the quoted spread and depth.

II. Hypotheses

Stock Characteristics and Dealer Quotation Behavior: Cross-Sectional Implications

We conjecture that the percentage of the trading time during which the market maker's quotes are at the inside is related to competition for order flow and the market-making profit. Competition for order flow among NASDAQ dealers varies greatly across stocks because there is wide variation in the number of market makers. There is also considerable cross-sectional variation in stock characteristics (e.g., spreads, trade sizes, and return volatility) that can influence dealers' incentives to post competitive quotes. Consequently, dealer quotation behavior is likely to vary across stocks.

To the extent that the expected market-making profit is larger for stocks with wider spreads, market makers have greater incentives to be at the inside for such stocks. Indeed, Chan, Christie, and Schultz (1995) show that although NASDAQ dealers do not usually post quotes on both sides of the inside spread, they do quote on both sides when the width of the inside spread is unusually large. The authors suggest that the simultaneous posting of bid and ask quotes at the inside may be motivated by the larger than average profits that can be earned from wider spreads.

If the spread is wide, public traders also have much to gain from submitting limit orders at the inside market because if they execute, the traders will have transacted at a better price than the price that would be obtained through placing a market order.[2] Barclay et al. (1999) estimate that at least 10% of dealer quotes (and inside quotes) are set by public limit orders for the first 100 NASDAQ stocks phased in under the new Securities and Exchange Commission (SEC) order-handling rules. To the extent that dealer quotes reflect the interest of limit-order traders, we expect dealer quotes to be at the inside more often for stocks with wider inside spreads. Based on these considerations, we conjecture that the percentage of time during which dealer quotes are at the inside is positively related to the width of the inside spread. Likewise, we expect the percentage of quotes at the inside to be higher for stocks with wider inside spreads.[3]

Theory suggests that dealers recoup their market-making costs (i.e., order-processing, inventory, and adverse-selection costs) from bid-ask spreads, and thus wider spreads reflect larger dealer costs (e.g., Copeland and Galai 1983; Easley and O'Hara 1987). In reality, however, the observed spreads can deviate from the actual market-making costs of dealers. Dealers have greater incentives to trade stocks that have observed spreads larger than market-making costs. Holding spreads constant, therefore, dealers are more likely to post competitive quotes for stocks with smaller actual market-making costs. Note also that, all things being equal, public traders are more likely to submit competitive limit orders (at the inside) for stocks with smaller adverse-selection costs.

Prior studies show that (1) inventory costs are larger for low-activity or high-risk stocks, (2) order-processing costs are lower for high-activity stocks, and (3) adverse-selection costs are greater for stocks with larger trade sizes and higher return volatility (e.g., Benston and Hagerman 1974; Stoll 1978; Easley and O'Hara 1987; Lin, Sanger, and Booth 1995). Hence, holding spreads constant, the percentage of quotes at the inside is likely to be higher for high-volume and low-risk stocks because dealers are likely to face smaller order-processing and inventory costs from these stocks. In contrast, the percentage of dealer quotes at the inside is likely to be lower for stocks with larger trade sizes and higher risk as dealers and limit-order traders face greater adverse-selection costs from these stocks.

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[2]For example, suppose that the current inside market quotes of a given stock are $20 bid and $20.50 ask, respectively. If a trader wants to buy the stock, he or she may either buy it at $20.50 immediately by placing a market order or submit a limit bid order at $20. Obviously, if the limit order executes, the trader would be paying less than the inside ask price.

[3]A market maker's decision to move from the noninside market to the inside market does not always narrow the existing inside spread. This is because the market maker can move to the inside market by joining other market makers who are already at the inside instead of posting a quote better than the existing inside market quote. Hence, for a given stock, a large percentage of dealer quotes can be at the inside while maintaining the wide inside spread.

The probability that a dealer's quote is at the inside for a given stock is likely to decrease with the number of dealers.[4] For instance, if a stock has two dealers and they post their quotes randomly, there is at least a 50% chance that a dealer's quote will be at the inside market. Similarly, if a stock has three dealers and they post their quotes randomly, there is at least a 33% chance that a dealer's quote will be at the inside. Hence, we expect that the percentage of time during which individual dealer quotes are at the inside will decrease with the number of dealers.

Brokers and market makers on NASDAQ routinely direct or preference customer order to any market maker who agrees to honor the best quoted price. For stocks with high degrees of order preferencing, dealers have little incentive to post aggressive quotes because such quotes do not necessarily lead to larger market shares. Indeed, prior studies offer both analytical predictions and experimental evidence regarding the detrimental effects of order preferencing on NASDAQ execution costs and quote aggressiveness.[5] For stocks with low levels of order preferencing, however, dealers have incentives to post aggressive quotes because such quotes are likely to increase their market shares. These considerations suggest that dealer quote aggressiveness would be lower for stocks with higher levels of preferenced order flow. We conjecture that quote aggressiveness is lower for stocks with more dealers because such stocks are likely to have higher levels of preferenced order flow. We expect these stocks to have higher levels of order preferencing because more dealers are competing for order flow. Although dealers can compete on price for order flow, they are likely to compete on other means also (such as payment for order flow) because these stocks already have narrow spreads.

In a recent study, Chung, Chuwonganant, and McCormick (Forthcoming) show that the price elasticity of dealer market share is positively related to the Herfindahl index during both pre- and post-decimalization periods (i.e., November 2000 and June 2001). This result suggests that aggressive quotes are more effective in raising market share in stocks with less competitive market structure. Because the Herfindahl index decreases with number of dealers, the preceding result indicates that dealers have an incentive to quote more aggressively for stocks with fewer dealers and that the percentage of time (quotes) at the inside decreases with number of dealers. This reinforces the negative effect of the number of dealers on the inside time discussed earlier. These considerations lead to our first hypothesis:

> H_1: The percentage of time (quotes) at the inside market is positively related to the inside spread and the number of transactions and negatively related to trade size, return volatility, and the number of dealers.

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[4] For a given stock, a dealer's time at the inside measures his or her quote aggressiveness, relative to the quote aggressiveness of other dealers. Similarly, of two stocks with the same number of dealers, the one with a higher mean percentage of dealers' time at the inside has greater dealer competition than the other.

[5] See Battalio and Holden (1996), Bloomfield and O'Hara (1998), and Bessembinder (1999).

Relation Between Price and Depth Quotes: Intertemporal Implications

In this section we provide a brief description of the limit-order display rule and present our hypotheses regarding how market makers establish their quantity quotes (depths) in relation to their price quotes. In particular, we offer our conjectures on how quoted depths vary with quoted prices, depending on whether the market maker's quotes are at the inside market.

The limit-order display rule requires that the market maker display all customer limit orders that are priced better than his or her quote or that add size to his or her quote at the inside price within 30 seconds of receipt, unless an exception applies. For instance, suppose that a market maker is quoting 1,000 shares at $20 bid. If the market maker receives a limit buy order of 2,000 shares at 20^1/_2$, he or she is required to revise the quote to reflect both the higher bid price and the larger bid size. Exceptions include block size orders (e.g., 10,000 shares or $200,000 market value), odd-lots orders, all-or-none orders, orders executed immediately on receipt, orders sent to another market maker or to a linked Electronic Communication Network (ECN), or orders requested by the customer not to be displayed. Customers do not have to ask for their limit orders to be displayed. It is the obligation of the market maker to display the orders unless instructed otherwise by the customer.

The preceding rule applies for individual dealers' inside quotes, regardless of the market inside. If the market maker receives an order that increases the depth, he or she must display it. The size requirement, however, is not an aggregate number. Suppose that the market maker is quoting (proprietary) 1,000 shares at $20 bid and receives a customer limit buy order of 1,000 shares at $20 bid. The market maker does not have to change the quote because he or she is already quoting 1,000 shares. However, the market maker may want to change his or her quote to 2,000 shares to show his or her proprietary interest plus the customer interest. Either way, the market maker cannot trade ahead of the customer limit order even though his or her proprietary interest was there first (i.e., the limit-order protection rule). Conversely, suppose that the customer buy order is for 1,100 shares. Then, the market maker is required to quote at least 1,100 shares.

We hold that the market maker's price and quantity quotes are interdependent and the quoted depth is likely to be larger when the market maker's quotes are at the inside market. To see this point, suppose that the market maker is quoting $20 bid for 1,000 shares (his or her proprietary interest) and receives a customer limit buy order for 1,000 shares at $20. If the inside market bid happens to be 20^1/_2$, the market maker may not want to change the quote from 1,000 to 2,000 shares (again, according to the rule, this is optional) because the order is far away from the inside market or the market maker may decide that his or her proprietary interest no longer needs to be quoted because the limit order is doing the market making for him or her.

However, suppose instead that the inside market bid happens to be $20. The market maker is already at the inside market bid because he or she wants to buy, perhaps for inventory reasons. Now, the market maker has received another limit buy order of 1,000 shares at $20. In this case, the market maker is likely to quote 2,000 shares because, if not, he or she could miss the opportunity to execute his or her proprietary interest if an order comes in. Thus, market makers are likely to post larger depths when their quotes are at the inside market.

The larger depth at the inside market can also be posited from the NASDAQ rule that dealers must make a two-sided continuous market. When dealers quote far from the inside, they are victims of this artificial rule, and they are likely to post minimum sizes (and irrelevant prices) to reduce the consequences of adverse selection. These considerations lead to our second hypothesis:

> H_2: For a given market maker, the quoted depth at the inside market is greater than the quoted depth at the noninside market.

The dealer spread is likely to be wide when neither side of the quote is at the inside. If the dealer steps up (down) the bid (ask) price to the inside market while maintaining the other side of the quote at the same position, the spread is likely to decrease.[6] If the dealer moves both the ask and bid prices from the noninside market to the inside market, the spread is likely to decrease even more. All things being equal, therefore, the dealer spread is likely to be narrower when the quote is at the inside. If the market maker's quoted depth is larger when the quote is at the inside, it follows that the quoted depth and spread are expected to move in opposite directions as the market maker changes position from the noninside market to the inside market, and vice versa. This leads to our next hypothesis:

> H_3: For a given market maker, the quoted depth varies inversely with the spread over time.

In the following sections we examine the empirical validity of these hypotheses using the inside and individual dealer quote data.

III. Data Source, Sample-Selection Method, and Descriptive Statistics

We obtain data for this study from NASTRAQ® trade and quote data. We use trade data, inside quote data, and dealer quote data for November 2000. To secure a sample of reasonably active stocks, we use only those with at least 50 daily transactions and with at least four market makers during the entire month. We omit

[6]The dealer spread will remain at the same level if the dealer concurrently raises the ask price as he or she steps up the bid price to the inside market or lowers the bid price when changing the ask price from the noninside market to the inside market. We do not believe this to be a likely dealer quotation behavior.

stocks with five-letter ticker symbols. (The fifth letter refers to an American Depositary Receipt, stock with several classes, a company that is currently delinquent in the periodic filings with the SEC, a company involved in bankruptcy proceedings, and a host of other things.) This leaves us with the final study sample of 1,392 stocks. We rank these 1,392 stocks according to the total number of transactions during the study period and then group them into three portfolios (464 stocks each) based on their trading frequencies.

Because the main purpose of this study is to analyze the quotation behavior of individual market makers, we include only those who are reasonably active in the study sample. Specifically, we use only market makers who submit at least five quotes per day during the study period. We do not include ECNs in the study sample because spreads and depths in ECNs are established by limit orders submitted by market makers, retail investors (e.g., Island), and large institutional investors. The bid side of an ECN quote may reflect the trading interest of a market maker and the ask side of the same quote may reflect the interest of another market maker or an institutional investor. Hence, the spread and depth quotes of a given ECN are unlikely to reveal dealer behavior. Although we do not view ECNs as market makers in the present study, our inside market quotes reflect the highest bid price and lowest ask price among quotes from all market participants, including ECNs.

We omit the following to minimize data errors: (1) quotes if either the ask or the bid is less than or equal to zero; (2) quotes if either the ask size or the bid size is less than or equal to zero; (3) quotes if the bid-ask spread is greater than \$10 or less than zero; (4) before-the-open and after-the-close trades and quotes; (5) trades if the price or volume is less than or equal to zero; (6) trade price, p_t, if $|(p_t - p_{t-1})/p_{t-1}| > 0.5$; (7) ask quote, a_t, if $|(a_t - a_{t-1})/a_{t-1}| > 0.5$; and (8) bid quote, b_t, if $|(b_t - b_{t-1})/b_{t-1}| > 0.5$.

We report descriptive statistics of the variables in Table 1. The results show that the mean share price varies considerably across our sample of stocks. The mean share price for the sample of most active stocks is \$35.19 and the corresponding figure is only \$10.90 for the sample of least active stocks. Similarly, the number of market makers differs significantly across our sample of stocks. The mean number of active market makers (who quote at least five quotes per day) for the sample of most active stocks is 23.81 and the corresponding figure is only 5.86 for the sample of least active stocks.

We find that return volatility (measured by the standard deviation of daily returns) is higher for active stocks. This result is consistent with the finding of previous studies that price changes and trading volume are positively related (see Karpoff 1987 for a review of the volume-volatility literature). The mean dealer spread is substantially greater than the mean inside market spread. For example, the mean dealer spread is \$1.35 whereas the mean inside market spread is only 21 cents. Similarly, the corresponding values for the percentage spread are 10.38% and 2.04%, respectively.

TABLE 1. Descriptive Statistics.

	Whole Sample		Portfolios Formed by Number of Trades					
			Most Active 464 Stocks		Medium Active 464 Stocks		Least Active 464 Stocks	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Share price ($)	21.12	21.84	35.19	27.60	17.27	15.42	10.90	10.74
Daily number of trades	1,152	3,860	3,131	6,234	239	71.62	87	25
Trade size ($)	13,615	11,269	20,590	12,598	11,951	9,273	8,302	7,551
Standard deviation of returns	0.068	0.030	0.071	0.027	0.066	0.029	0.067	0.034
Number of market makers	13.41	9.97	23.81	10.66	10.55	2.63	5.86	2.04
Inside market spread ($)	0.21	0.13	0.19	0.11	0.21	0.13	0.22	0.14
Inside market spread (%)	2.04	1.87	0.81	0.59	1.95	1.41	3.35	2.21
Dealer spread ($)	1.35	0.95	1.80	1.03	1.32	0.93	0.92	0.64
Dealer spread (%)	10.38	7.00	6.83	3.70	11.05	7.09	13.24	7.86
Bid depth (in round lots)	4.49	5.16	3.45	3.53	4.54	5.36	5.47	6.07
Ask depth (in round lots)	4.39	4.80	3.38	2.37	4.17	3.79	5.60	6.84
Total depth (in round lots)	8.87	9.73	6.83	5.78	8.71	9.01	11.08	12.67

Note: We obtain data for this study from NASTRAQ® Trade and Quote Data. We use trade data, inside quote data, and dealer quote data for November 2000. To secure a sample of reasonably active stocks, we use only those with at least 50 daily transactions and with at least four market makers during the entire month. We omit stocks with five-letter ticker symbols. This leaves us with the final study sample of 1,392 stocks. We rank these 1,392 stocks according to the total number of transactions during the study period and then group them into three portfolios (464 stocks each) based on their trading frequencies. Because the main purpose of this study is to analyze the quotation behavior of market makers, we use only those market makers who submit at least five quotes per day during the study period. Share price is measured by the mean transaction price during the study period. Inside market spread ($) is the difference between the lowest ask and highest bid. Inside market spread (%) is obtained by dividing inside market spread ($) by the midpoint of the quote. Dealer spread ($) is the difference between the ask price and the bid price of a given dealer. Dealer spread (%) is obtained by dividing dealer spread ($) by the midpoint of the quote. We report the average depth (in round lots) at the individual dealers' inside quotes.

TABLE 2. Percentage of Time (Quotes) at the Inside Market.

	Whole Sample		Portfolios Formed by Number of Trades: Most Active 464 Stocks		Medium Active 464 Stocks		Least Active 464 Stocks	
	% of Time	% of Quotes	% of Time	% of Quotes	% of Time	% of Quotes	% of Time	% of Quotes
Neither the bid nor the ask is at the inside market	73.1	58.2	81.9	63.9	65.8	53.4	50.4	44.2
Only the bid is at the inside market	12.6	19.5	8.8	17.2	16.0	21.7	21.8	24.7
Only the ask is at the inside market	11.9	18.4	8.2	16.5	15.1	19.9	21.1	23.1
Both the bid and the ask are at the inside market	2.4	3.9	1.1	2.4	3.1	5.0	6.7	8.0

Note: This table shows the average percentage of time the market maker is at the inside market. We first calculate the percentage of time during which each dealer is at the inside market (i.e., the number of seconds at the inside divided by the total number of seconds during which the market is open) for each stock in our study sample. We then calculate the mean value of this percentage across all market makers for each stock. Finally, we calculate the average of this mean percentage for the entire study sample of 1,392 stocks and for each portfolio of 464 stocks. Similarly, we calculate the average percentage of quotes at the inside market (i.e., the number of quotes at the inside divided by the total number of quotes).

We find that the percentage spread varies greatly across our sample of stocks. For instance, the mean inside market spread for the sample of most active stocks is 0.81% whereas the corresponding value for least active stocks is 3.35%. Similarly, the mean dealer spread for most active stocks is 6.83% whereas the corresponding value for least active stocks is 13.24%. Table 1 also shows that the average depth at the individual dealers' inside quotes of most active stocks is smaller than that of least active stocks.

IV. Empirical Findings

In this section we examine cross-sectional and intertemporal variations in dealer quotes and test our conjectures stipulated in section II.

Frequency of the Inside Market Quotes

To analyze the quotation behavior of market makers, we first examine how frequently they post competitive quotes. In Table 2 we show the average percentage of the total trading time during which the market maker is at the inside. We obtain data on inside quotes from the NASTRAQ® inside quote file. Hence, these quotes reflect the highest bid price and lowest ask price among quotes from all market participants (e.g., NASDAQ dealers, limit-order trades, and ECNs). We first calculate the percentage of the total trading time each dealer is at the inside market (i.e., the number of seconds at the inside divided by the total number of seconds during which the market is open) for each stock in our study sample. We then calculate the mean value of this percentage across all market makers for each stock. Finally, we calculate the average of this mean percentage for the entire study sample of 1,392 stocks and for each portfolio of 464 stocks. Similarly, we calculate the average percentage of quotes at the inside market (i.e., the number of quotes at the inside divided by the total number of quotes).

The mean percentage of the total trading time during which neither the bid nor the ask is at the inside market is 73.1% for our whole study sample. The percentage of time during which the market maker's quotes are at either the inside bid or the inside ask is only 24.5%. Market makers rarely (2.4% of time) post competitive prices on both sides of the quote. We obtain qualitatively similar results from the percentage of quotes. For instance, the percentage of quotes that are noncompetitive on both sides of the quote is 58.2% and the percentage of quotes that are competitive on one side of the quote is 37.9%. These results are analogous to the finding of previous studies for NYSE stocks that market makers selectively post their trading interests only on one side of the quote. For example, Blume and Goldstein (1997) show that the regional exchanges generally do not post both the best bid and the best ask prices at the same time for NYSE-listed stocks. Kavajecz (1999) finds evidence that NYSE specialists selectively provide liquidity (and thereby protect themselves from informed traders) by posting their trading interest on only one side of the market 25% to 50% of the time.

Table 2 shows that the percentage of quotes at the inside is higher for stocks with a smaller number of transactions. For the group of least active stocks, the percentage of quotes that are competitive on one side of the quote is 47.8%, whereas the corresponding figure is only 33.7% for the group of most active stocks. Similarly, the percentage of time during which the market maker's quotes are at either the inside bid or the inside ask is 42.9% for the group of least active stocks and 17% for the group of most active stocks. In addition, we find that the percentage of time during which both the bid and ask quotes are at the inside market is 6.7% for the group of least active stocks and 1.1% for the group of most active stocks.

The negative correlation between the number of trades and the percentage of time (quotes) at the inside market shown in Table 2 is likely to be spurious because both variables are strongly correlated with the number of market makers. That is, because the number of trades is positively correlated with the number of market makers and stocks with a larger number of market makers generally have a lower percentage of time at the inside market, the negative correlation between the number of trades and the percentage of time at the inside may simply reflect the negative correlation between the number of market makers and the percentage of time at the inside market. We present additional evidence regarding cross-sectional relations between quote aggressiveness and stock attributes in the next section.

To shed further light on the nature of competition among market makers, we examine interdealer differences in quote aggressiveness for our sample of stocks. We cluster our sample stocks into 10 portfolios (139 stocks in each portfolio) according to the number of market makers. For each stock within each portfolio, we rank market makers according to the percentage of time at the inside on at least one side of the quote (*PTINS*) and then calculate the cross-sectional average of *PTINS* for each portfolio.

Table 3, Panel A shows the mean, maximum, and minimum values of the number of market makers for each portfolio; Panel B shows the mean, maximum, and minimum values of *PTINS* within each portfolio; and Panel C shows the mean values of *PTINS* for the 20 most aggressive market makers within each portfolio. For instance, in the case of portfolio 6, there are on average about 11 market makers for each stock and the most aggressive market maker is at the inside 60.16% of time, the second most aggressive one is at the inside 51.15% of time, and so on. Notice that the percentage of time at the inside declines gradually across dealers within each portfolio. Hence, the inside market quotes for a given stock are established and shared by many competing dealers rather than by a small number of dominant dealers.

Stock Characteristics and Dealer Quotation Behavior: Test of Hypothesis 1

To examine how dealer quotation behavior is related to the attributes of underlying stocks, we estimate the following regression models:

$$PTINS_i \text{ or } PQINS_i = \alpha_0 + \alpha_1 \log(NTRA_i) + \alpha_2 \log(NMM_i) + \alpha_3 \log(TSIZE_i) + \alpha_4 RISK_i + \alpha_5 SPRD_i + \varepsilon_i, \qquad (1)$$

where $PTINS_i$ is the average percentage of time during which dealer quotes are at the inside market on at least one side of the quote for stock i, $PQINS_i$ is the average percentage of dealer quotes that are at the inside market on at least one side of the quote, $NTRA_i$ is the average daily number of trades, NMM_i is the number of dealers, $TSIZE_i$ is the average dollar trade size, $RISK_i$ is the standard deviation of daily stock returns, $SPRD_i$ is the average inside percentage spread, and ε_i is an error term. We use the log of *NTRA*, *NMM*, and *TSIZE* because these variables are highly skewed.

Table 4 shows the regression results. The results show that both *PTINS* and *PQINS* are positively related to log(*NTRA*) and *SPRD*, and negatively to log(*NMM*), log(*TSIZE*), and *RISK*. The positive relation between log(*NTRA*) and *PTINS* (*PQINS*) is consistent with our hypothesis that market makers have greater incentives to be at the inside for high-activity stocks as they face lower

TABLE 3. Percentage of Time at the Inside Market for Most Aggressive Market Makers.

	Portfolio									
	1	2	3	4	5	6	7	8	9	10
Panel A. Number of Market Makers										
Mean	3.71	5.38	6.87	8.35	9.59	11.24	13.31	16.61	22.58	39.18
Maximum	5	6	8	9	10	12	15	19	27	61
Minimum	2	5	6	8	9	10	12	15	19	27
Panel B. Percentage of Time at the Inside for Individual Market Makers										
Mean	61.06	54.10	47.69	42.35	37.50	32.54	28.41	23.74	18.73	14.34
Maximum	99.97	99.81	99.35	93.70	90.20	94.31	91.14	85.47	100.00	95.97
Minimum	18.30	1.69	1.56	0.38	0.00	0.03	0.00	0.00	0.00	0.00
Panel C. Percentage of Time at the Inside for Most Aggressive Market Makers										
1	76.60	73.47	69.72	65.92	64.39	60.16	56.91	53.23	50.93	51.21
2	63.46	63.13	60.37	56.57	54.19	51.15	46.93	44.64	41.17	40.95
3	53.60	55.33	52.58	49.97	47.14	44.26	40.63	38.65	36.17	35.84
4	44.57	47.51	47.24	44.94	42.12	38.94	36.61	34.19	32.32	32.83
5	38.31	38.57	41.11	40.84	37.30	35.29	33.44	31.00	28.73	29.90
6		31.73	34.26	35.88	33.16	31.71	30.43	28.38	26.20	27.19
7			25.19	29.91	29.74	28.11	27.75	25.86	24.24	24.99
8			17.88	22.64	24.64	24.46	24.87	23.45	21.91	23.04
9				17.92	18.78	20.77	21.97	21.38	20.26	21.50
10					12.78	16.70	18.65	19.27	18.53	19.71
11						11.99	15.52	17.41	16.96	18.45
12						7.92	12.04	15.36	15.64	17.39
13							9.61	13.12	14.39	16.40
14							7.46	10.64	13.07	15.27
15							4.18	7.90	11.68	14.41
16								6.17	10.28	13.52
17								4.69	9.09	12.73
18								2.86	7.76	11.87
19								3.76	6.04	11.08
20									5.11	10.32

Note: This table shows the average percentage of time the market maker is at the inside market. We first calculate the percentage of time during which each dealer is at the inside market (i.e., the number of seconds at the inside divided by the total number of seconds during which the market is open) for each stock in our study sample. We then calculate the mean value of this percentage across all market makers for each stock. Finally, we calculate the average of this mean percentage for the entire study sample of 1,392 stocks and for each portfolio of 464 stocks.

order-processing and inventory costs from these stocks.[7] The positive relation between *SPRD* and *PTINS* (*PQINS*) supports our conjecture that market makers and limit-order traders have greater incentives to be at the inside for stocks with wider

[7] We note that the positive correlation between log(*NTRA*) and *PTINS* (*PQINS*) can also arise if there are more limit orders at the inside market for stocks with higher trading frequencies.

TABLE 4. Cross-Sectional Relation Between Dealer Quotation Behavior and Stock Characteristics.

Dependent Variables		Explanatory Variables							
		Intercept	log(*NTRA*)	log(*NMM*)	log(*TSIZE*)	*RISK*	*SPRD*	Adj. R^2	F-value
PTINS	Coefficient	112.48	0.70	−16.23	−4.44	−72.34	1.90	0.87	1873.87
	t-statistic	37.79	2.36	−25.19	−15.19	−10.63	10.90		
	(p-value)	(.0001)	(.0184)	(.0001)	(.0001)	(.0001)	(.0001)		
PQINS	Coefficient	106.25	1.63	−12.75	−3.81	−52.27	0.72	0.83	1376.20
	t-statistic	47.28	7.30	−26.22	−17.28	−10.17	5.44		
	(p-value)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)		
PQRNT	Coefficient	52.96	−4.43	−4.03	0.17	−36.14	0.64	0.85	1527.22
	t-statistic	26.55	−22.39	−9.33	0.86	−7.92	5.44		
	(p-value)	(.0001)	(.0184)	(.0001)	(.3907)	(.0001)	(.0001)		
PAWAY	Coefficient	−42.11	−0.33	11.03	5.20	62.95	−0.17	0.82	1241.83
	t-statistic	−16.72	−1.30	20.24	20.99	10.93	−1.17		
	(p-value)	(.0001)	(.1932)	(.0001)	(.0001)	(.0001)	(.2434)		

Note: This table shows the results of the following models: $PTINS_i$, $PQINS_i$, $PQRNT_i$, or $PAWAY_i = \alpha_0 + \alpha_1\log(NTRA_i) + \alpha_2\log(NMM_i) + \alpha_3\log(TSIZE_i) + \alpha_4 RISK_i + \alpha_5 SPRD_i + \varepsilon_i$, where $PTINS_i$ is the percentage of time during which dealer quotes are at the inside market on at least one side of the quote for stock i, $PQINS_i$ is the percentage of dealer quotes that are at the inside market on at least one side of the quote for stock i, $PQRNT_i$ is the percentage of quote revisions that occur when no trade has taken place within 30 seconds, $PAWAY_i$ is the percentage of quote revisions made to stay away from the inside, $NTRA_i$ is the average daily number of trades for stock i, NMM_i is the number of dealers for stock i, $TSIZE_i$ is the average dollar trade size for stock i, $RISK_i$ is standard deviation of daily stock returns for stock i, $SPRD_i$ is the average inside spread of stock i, and ε_i is the error term. We use the log of *NTRA*, *NMM*, and *TSIZE* because these variables are highly skewed.

spreads because the expected market-making and trading profits are larger for such stocks. It is unlikely that the observed positive correlation between *SPRD* and either *PTINS* or *PQINS* is due to reverse causality (e.g., the inside spread is determined by dealer or limit-order trader behavior). This is because the higher percentage of time (or quotes) at the inside is likely to result in narrower, not wider, spreads.

The negative relation between log(*NMM*) and *PTINS* (*PQINS*) reflects the fact that the probability that a market maker's quotes are at the inside is likely to decrease with the number of dealers submitting the quotes. This result is also consistent with the notion that dealers' incentive to post aggressive quotes decreases with the extent of order preferencing. The negative relation between log(*TSIZE*) and *PTINS* (*PQINS*) supports the idea that market makers and traders have smaller incentives to be at the inside for stocks with larger trade sizes because they face greater adverse-selection problems from these stocks. Similarly, the negative relation between *RISK* and *PTINS* (*PQINS*) is in line with the idea that market makers have smaller incentives to be at the inside for riskier stocks because they face greater inventory and adverse-selection problems.[8]

Overall, our findings suggest that NASDAQ dealers' propensity to post the inside market quotes is strongly correlated with stock attributes. The observed directional relations between the propensity and stock attributes are consistent with our conjecture that dealer quotation behavior is largely determined by competition for order flow and the market-making profit.

To shed further light on dealer quotation behavior, we calculate an alternative measure of dealer quote aggressiveness: the percentage of quote revisions that involve no trades (*PQRNT*). For this, we first identify quote revisions that were not preceded or followed by a trade within 30 seconds and divide the number of these quote revisions by the total number of quote revisions for each dealer. Then, we calculate the mean value of this ratio across dealers for each stock. To the extent that quote revisions that occur in the absence of any trades reflect dealers' predisposition to compete on price, we expect *PQRNT* to be significantly related to stock attributes as well.

Table 4 shows that *PQRNT* is positively related to *SPRD* and negatively to *RISK* and log(*NMM*). The positive relation between *PQRNT* and *SPRD* supports the view that market makers have greater incentives to compete on price for stocks with wider spreads because the expected market-making revenue is larger for such stocks. The negative relation between *PQRNT* and *RISK* supports the notion that

[8] To assess the robustness of our results, we also estimate equation (1) using the pooled data of individual dealer quotes. We first rank dealers according to the number of stocks they cover and choose the top 50 dealers. We then stack the stocks covered by each dealer and pool them across the 50 dealers. Finally, we estimate the model using the pooled data of stock-dealer observations. The results are qualitatively similar to those that are based on the mean *PTINS* (*PQINS*) for each stock, although R^2 values for the *PTINS* (*PQINS*) equation are considerably lower.

market makers have smaller incentives to compete on price for riskier stocks. The negative relation between *PQRNT* and log(*NMM*) is consistent with the notion that dealers' need to compete on price for order flow decreases with the extent of order preferencing. Because *PQRNT* is less likely affected by the sheer number of market makers for a given stock, we interpret this result as stronger evidence of the negative effect of order preferencing on dealer quote aggressiveness. Finally, the negative correlation between *PQRNT* and log(*NTRA*) may simply reflect that for actively traded stocks, it is less likely to observe quote revisions that do not involve trades.

We also perform regression analysis using the percentage of quote revisions that are made to stay away from the inside (*PAWAY*) as the dependent variable. We measure *PAWAY* by the ratio of the number of quote revisions that maintain a dealer's quote away from the inside to the total number of quote revisions. Because *PAWAY* is negatively related to *PTINS* (*PQINS*) by construction (e.g., the correlation coefficient between *PAWAY* and *PTINS* is -0.93), we perform an alternative test of hypothesis 1 by regressing *PAWAY* on the same stock attributes that were used in the *PTINS* (*PQINS*) model. As expected, Table 4 shows that the signs of regression coefficients in the *PAWAY* equation are opposite those in the *PTINS* (*PQINS*) equation. In particular, the results show that *PAWAY* is significantly and positively related to log(*NMM*), log(*TSIZE*), and *RISK*. We interpret the positive relation between *PAWAY* and log(*NMM*) as stronger evidence of the negative effect of order preferencing on dealer quote aggressiveness than the negative relation between *PTINS* (*PQINS*) and log(*NMM*) shown earlier because *PAWAY* is less likely affected by the number of market makers.

Intertemporal Relation Between the Quantity and Price Quotes

In this section we analyze how NASDAQ dealers establish their quantity quotes in relation to price quotes. Our focus here is the intertemporal association between the price and quantity quotes of individual dealers. Using time-series quote data for each dealer, we present a detailed analysis of how market makers interactively determine their quantity and price quotes.

To determine whether market makers' depth quotes are linked to their price quotes, we first analyze whether asymmetry in price quotes is accompanied by asymmetry in depth quotes. Specifically, we test whether market makers post different depths between the bid and ask if only one side of the quote is at the inside. For instance, hypothesis 2 suggests that the bid depth will be greater than the ask depth when the bid is at the inside but the ask is not. Conversely, the ask depth is expected to be greater than the bid depth when only the ask is at the inside. We identify all of the dealers who make a market for each stock and estimate the following regression model for each dealer:

$$DIFDEP = \beta_0 + \beta_1 D_{NI} + \beta_2 D_{IN} + \Sigma\beta_i \, Intraday\ time\ dummy_i + \varepsilon, \quad (2)$$

where *DIFDEP* is defined as (*Ask depth* − *Bid depth*)/[(*Ask depth* + *Bid depth*)/2]; D_{NI} is a dummy variable that equals 1 if the ask price is at the inside and the bid price is not at the inside (quote class (*N,I*) hereafter, where *N* denotes the noninside market quote for the bid and *I* denotes the inside market quote for the ask), and 0 otherwise; D_{IN} is a dummy variable that equals 1 if the bid price is at the inside and the ask price is not at the inside (quote class (*I,N*) hereafter, where *I* denotes the inside market bid quote and *N* denotes the noninside market ask quote), and 0 otherwise; βs are the regression coefficients; and ε is an error term. We also include in the regression the six dummy variables that represent the first and last three 30-minute intervals of the trading day to control for any intraday variation in *DIFDEP*.

The intercept measures the average *DIFDEP* of quote classes (*N,N*) and (*I,I*). The coefficient (β_1) for D_{NI} measures the difference in *DIFDEP* between quote class (*N,I*) and quote classes (*N,N*) and (*I,I*). Similarly, the coefficient (β_2) for D_{IN} measures the difference in *DIFDEP* between quote class (*I,N*) and quote classes (*N,N*) and (*I,I*). If the market maker tends to quote larger depths at the inside market than at the noninside market, we expect β_1 to be positive and β_2 to be negative.

Table 5, Panel A shows the results of the regression (2) for our entire study sample and for each portfolio of 464 stocks. For each dummy variable, we report the average coefficient estimate from dealer-by-dealer regressions. To determine whether the dummy variable coefficients are significantly different from zero, we calculate z-statistics with their respective p-values. We obtain the z-statistic by adding individual regression t-statistics across dealers and then dividing the sum by the square root of the number of regression coefficients.[9]

The regression results show that market makers post larger depths on the side of the quote at the inside. For example, when the market maker's bid quote is at the inside but the ask quote is not, the bid depth is larger than the ask depth (i.e., $\beta_2 < 0$). Conversely, when the ask quote is at the inside but bid quote is not, the market maker quotes a larger depth at the ask (i.e., $\beta_1 > 0$). We obtain qualitatively similar results from stocks of differing activity levels. These results show that when market makers actively compete for order flow with price, they tend to quote larger depths. This may reflect the market makers' attempt to neutralize their inventory imbalances by actively seeking order flows with the inside market quote.

Regression (2) uses only partial information regarding the quoted depth, that is, whether the bid depth is different from the ask depth. The model does not make use of information regarding the difference in the bid (ask) depth between inside and noninside quotes. Hence, we examine the robustness of the results by testing whether the average depth for the inside market quotes is significantly

[9] See Warner, Watts, and Wruck (1988) and Chung, Van Ness, and Van Ness (1999) for this method.

TABLE 5. Depth Quotes as a Function of Price Quotes.

		Whole Sample	Most Active 464 Stocks	Medium Active 464 Stocks	Least Active 464 Stocks
Panel A. $DIFDEP = \beta_0 + \beta_1 D_{NI} + \beta_2 D_{IN} + \Sigma\beta_i$ *Intraday time dummy*$_i + \varepsilon$					
Intercept	Mean coefficient	0.0090	0.0080	0.0041	0.0218
	z-statistic (p-value)	23.90 (.0001)	21.17 (.0001)	5.47 (.0001)	12.63 (.0001)
D_{NI}	Mean coefficient	0.2962	0.3072	0.2698	0.2994
	z-statistic (p-value)	563.72 (.0001)	560.02 (.0001)	180.06 (.0001)	109.93 (.0001)
D_{IN}	Mean coefficient	−0.2918	−0.2910	−0.2783	−0.3193
	z-statistic (p-value)	−557.69 (.0001)	−541.43 (.0001)	−189.04 (.0001)	−119.33 (.0001)
Panel B. *Total depth* $= \beta_0 + \beta_1 D_{NI} + \beta_2 D_{IN} + \beta_3 D_{II} + \Sigma\beta_i$ *Intraday time dummy*$_i + \varepsilon$					
Intercept	Mean coefficient	6.1332	5.4386	6.4012	7.8365
	z-statistic (p-value)	2324.47 (.0001)	2416.41 (.0001)	724.22 (.0001)	390.79 (.0001)
D_{NI}	Mean coefficient	1.9702	1.7279	2.0774	2.5416
	z-statistic (p-value)	339.45 (.0001)	339.16 (.0001)	115.78 (.0001)	68.33 (.0001)
D_{IN}	Mean coefficient	1.9663	1.6039	2.1219	2.8292
	z-statistic (p-value)	334.73 (.0001)	327.46 (.0001)	118.89 (.0001)	73.60 (.0001)
D_{II}	Mean coefficient	2.6125	1.9879	2.7989	4.2338
	z-statistic (p-value)	158.30 (.0001)	127.12 (.0001)	73.08 (.0001)	61.91 (.0001)
Panel C. log(*Total depth*) $= \beta_0 + \beta_1$ log(*Spread*) $+ \Sigma\beta_i$ *Intraday time dummy*$_i + \varepsilon$					
Intercept	Mean coefficient	1.2707	1.2645	1.2231	1.3796
	z-statistic (p-value)	5506.14 (.0001)	5682.07 (.0001)	1596.23 (.0001)	870.27 (.0001)
log(*Spread*)	Mean coefficient	−0.1659	−0.1501	−0.1680	−0.2241
	z-statistic (p-value)	−515.20 (.0001)	−464.52 (.0001)	−212.38 (.0001)	−130.41 (.0001)

(Continued)

TABLE 5. Continued.

Panel D. Percentage of Depth Quotes That Are Equal to the Mandatory Minimum (100 Shares)

	%	*t*-statistic	%	*t*-statistic	%	*t*-statistic	%	*t*-statistic
Bid is at the inside market	14.22	269.31***	12.25	233.49***	16.22	130.82***	18.47	76.76***
Bid is not at the inside market	62.88		66.53		60.06		53.16	
Ask is at the inside market	13.57	279.51***	11.68	239.08***	15.52	138.30***	17.63	81.76***
Ask is not at the inside market	63.47		66.92		61.20		53.62	

Note: Panels A, B, and C show the results of regression models (2), (3), and (4), respectively. *DIFDEP* is defined as (*Ask depth* − *Bid depth*)/[(*Ask depth* + *Bid depth*)/2]; *Total depth* is the summation of bid and ask depths; D_{NI} is a dummy variable that equals 1 if the ask price is at the inside market and the bid price is smaller than the best bid (i.e., quote class (*N,I*), where *N* denotes the noninside market quote for the bid and *I* denotes the inside market quote for the ask), and 0 otherwise; D_{IN} is a dummy variable that equals 1 if the bid price is at the inside market and the ask price is greater than the best ask (i.e., quote class (*I,N*), where *I* denotes the inside market bid quote and *N* denotes the noninside market ask quote), and 0 otherwise; and D_{II} is a dummy variable that equals 1 if both the bid and ask prices are at the inside market, and 0 otherwise. We also include in the regression the six dummy variables representing the first and last three 30-minute intervals of the trading day. For each variable, we report the average coefficient estimate from dealer-by-dealer regressions and *z*-statistics with their respective *p*-values. We obtain the *z*-statistic by adding individual regression *t*-statistics across dealers and then dividing the sum by the square root of the number of dealers. Panel D shows the percentage of depth quotes that are equal to the mandatory minimum of 100 shares when the quote is at the inside market and when the quote is not at the inside market.

***Significant at the 1% level (testing whether the difference is significantly different from zero).

different from the average depth for the noninside market quotes. For this, we estimate the following regression model for each market maker and aggregate the estimated regression coefficients across market makers:

$$Total\ depth = \beta_0 + \beta_1 D_{NI} + \beta_2 D_{IN} + \beta_3 D_{II} + \Sigma\beta_i\ Intraday\ time\ dummy_i + \varepsilon, \quad (3)$$

where D_{xy} equals 1 if quote class is (x,y), and 0 otherwise, and all other variables are as defined previously. The intercept measures the average depth of quote class (N,N). The coefficients β_1, β_2, and β_3 measure the differences between the average depth for quote class (N,N) and the average depth for quote classes (N,I), (I,N), and (I,I), respectively. If market makers post larger depths for the inside market quotes compared with the noninside market quotes, we expect β_1, β_2, and β_3 to be positive. In addition, we expect the estimate of β_3 to be greater than the estimate of either β_1 or β_2.

We present the regression results in Panel B of Table 5. We find that the estimated coefficients for all three dummy variables are positive and significant. Furthermore, the estimates of β_3 are greater than the estimates of either β_1 or β_2 in all regressions.[10] These results corroborate our earlier finding that market makers quote larger depths when they post quotes that are at the inside market. On the whole, these results show that market makers' depth quotes are dependent on their spread quotes and they tend to be aggressive in depth quotes when they are actively seeking order flow through price quotes.

Frequency of the Minimum Depth

If a market maker's quote is at the inside, it will most likely indicate that he or she wants to trade on his or her own (for inventory or informational reasons, or both) or on behalf of his or her customers. In contrast, if the market maker's quote is away from the inside, he or she may quote a size that is less meaningful. To the extent that market makers want to be either on the buy or sell side of the market, only one side of the quote is likely to expose their true interest and the other side is done out of obligation, as NASDAQ requires two-sided quotes. Thus, market makers are likely to post the regulatory minimum depth of 100 shares at their noninside market quotes. As a result, the minimum-depth percentage is expected to be higher for the noninside market quotes than for the inside market quotes.

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[10]We expect β_3 to be equal to $\beta_1 + \beta_2$ if the dealer quotes the same inside depth regardless of whether he or she is at the inside on only one side or both sides. Suppose, for example, that the dealer quotes 1,000 shares whenever he or she is at the inside and 100 shares when not at the inside. Then, the dealer's total quoted depth for quote classes (N,N), (N,I), (I,N), and (I,I) will be 200, 1,100, 1,100, and 2,000, respectively. In this case, the estimated values of β_0, β_1, β_2, and β_3 will be 200, 900, 900, and 1,800, and thus $\beta_3 = \beta_1 + \beta_2$. Our empirical results show that β_3 is somewhat smaller than $\beta_1 + \beta_2$, suggesting that, in the previous example, the dealer's quoted depth for quote class (I,I) is smaller than 2,000.

We show the empirical results in Panel D of Table 5. For the whole sample, we find that the average percentage of the minimum mandatory depth (100 shares) is 62.88% when the market maker's bid is not at the inside and only 14.22% when the bid is at the inside. Similarly, the average percentage of the minimum depth is 63.47% when the ask is not at the inside and only 13.57% when the ask is at the inside. The results of t-tests show that the difference is highly significant in both cases. We find similar results when we replicate the tests using data from each sample of 464 stocks. These results support our conjecture that NASDAQ dealers are more likely to post the minimum depth when they quote the noninside market prices. Hence, the magnitude of quoted depths at noncompetitive prices is not only smaller but also less meaningful (because it frequently reflects the mandatory minimum) than the magnitude of quoted depths at the inside market.

Intertemporal Correlation Between the Quoted Depth and Spread of Market Makers

Having found that the quoted depth at the inside market is indeed greater than the quoted depth at the noninside market and given that dealer spread is likely to be narrower when the quote is at the inside market, we now examine whether there is a contemporaneous negative correlation between the quoted depth and the quoted spread, as we stipulate in hypothesis 3. We estimate the following regression model for each market maker using the time-series data for each stock:

$$\log(\textit{Total depth}) = \beta_0 + \beta_1 \log(\textit{Spread}) + \Sigma\beta_i \textit{ Intraday time dummy}_i + \varepsilon, \quad (4)$$

We include six dummy variables in the regression to control for intraday variation in the depth and spread documented in previous studies (e.g., Lee, Mucklow, and Ready 1993; Chung and Van Ness, 2001). Because we use the logarithm of the spread and depth in the regression, the estimated coefficient measures the elasticity of the depth with respect to changes in the spread (i.e., percentage change in the depth given 1% change in the spread). We present the regression results in Panel C of Table 5. Consistent with hypothesis 3, we find that the mean value of the β_1 estimate is significant and negative for our entire study sample as well as for each of the three subsamples.

V. Summary and Concluding Remarks

Although market makers have two control variables (price and quantity) under their discretion, we know little about how they use them. In this study, we perform cross-sectional and time-series analyses of how NASDAQ dealers use both dimensions of the quote to promote their interest within the confinement of their role as liquidity providers. Our results indicate that NASDAQ dealers selectively reflect their proprietary interest in the quote consistent with profit-maximizing behavior. We find that dealers quote at the inside market more frequently for stocks with greater market-making revenues and smaller market-making costs. Our results also indicate that market makers selectively add their proprietary interest to quoted depths, depending on whether their quotes are at the inside. We show that this quotation behavior leads to the negative intertemporal correlation between the quoted depth and spread.

Although the present study identifies certain regularities in dealer quotation behavior, there are many questions that remain unanswered. Although we find evidence that NASDAQ dealers post different depths depending on whether their price quotes are at the inside, the present study offers little insight on how they change their price and quantity quotes in response to outside shocks. We do not establish an intertemporal link between these quote changes and concurrent shocks such as changes in trade size, price volatility, and the number of trades. Establishing such a link would be an interesting area for future research. Although this study suggests that market makers' depth quotes are a function of price quotes, it is also possible that the causality can go the other way. For instance, having limit orders in addition to their own interest or having accumulated a lot of inventory, market makers may want to be at the inside to generate executions. An empirical clarification of the causality issue will undoubtedly shed further light on the behavior of market makers.

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