THREE ESSAYS ON NYSE SPECIALIST STRATEGIES

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dedicated to the Owner of the Names

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THREE ESSAYS ON NYSE SPECIALIST STRATEGIES

In our first essay, we investigate how the New York Stock Exchange (NYSE) specialists react to the changes in market variables while making participation decisions to the posted quotes by analyzing specialists' choices to undercut or add depth to the limit order book. We find that the primary factor that affects the participation strategy of the specialists in the current period is the changes in the best prices and depths on the limit order book. In addition, specialists participate to the posted quotes more for volatile or low volume stocks. The levels of specialists' participation in the posted quotes have predictive power over future stock returns. This predictive power is stronger for short-term returns.

In our second essay, we analyze trading strategies of the specialists conditional on their decisions to participate in the current posted quotes. We find that the specialists use limit order book asymmetry and cumulative order imbalance as two information sources about the true security value. If the relative size of the market order is high, specialists choose not to participate and let the market order trade with the limit order book. Consistent with the theoretical results in the previous literature, specialists trade more aggressively when the spread is large. We also find significant inventory effects. The specialists trade more aggressively, if the trade with the incoming market order restores their inventories.

Our third essay shows that there exist significant differences between the performances of *individual* specialists in terms of quotes, depths, spreads and execution

costs. We find that, as the trading frequency increases, order processing costs increase for both the specialist firms and individual specialist portfolios, which is consistent with the hypothesis that profits from active stocks subsidize inactive stocks. We also show that individual NYSE specialists differ significantly in their participation strategies to the posted quotes and trades. This suggests that there are significant differences in the execution costs between specialists, because they use different strategies.

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Chapter 1

Participation Strategy of the NYSE Specialists to the Posted Quotes

Abstract

Using 2001 NYSE system order data in the decimal pricing environment, we analyze how the specialists react to the changes in market variables while making participation decisions to the posted quotes. We analyze the specialists' decision to undercut or add depth to the limit order book. We distinguish bid and ask side of the quotes. We find that the primary factors that affect the participation strategy of the specialists to the current posted quotes are the changes in the best prices and depths on the limit order book since the previous quotes. In addition, specialists participate to the posted quotes more for low-volume or high price stocks. Unlike some previous studies, we find significant inventory effects providing some evidence that the specialist actively manages his inventory. The levels of specialists' participation to the posted quotes have predictive power over future stock returns. This predictive power is stronger for short-term returns. Overall, our results indicate that on average specialists quote in a manner, which is consistent with their affirmative obligations.

1. Introduction

New York Stock Exchange (NYSE) specialists are responsible for making markets for the stocks assigned to them. Their primary obligation is to ensure that there exists a fair and orderly market in their stocks. They should be willing to trade when other traders are unwilling to trade and the bid-ask spread should not be too wide. Also the specialists should intervene to prevent large price jumps, and create price continuity.[1] The NYSE uses the average width of the quoted bid-ask spread, the average depth of the quotes, the number of large price jumps, and the average size of price reversals to evaluate specialists' performances. The specialists' also have negative obligations that restrict their trading. Specialists cannot trade for their own accounts if there exist public orders at the same price or better. In addition, they should not trade with limit orders in order not to take the liquidity available to public traders. [2]

In this paper, we analyze three fundamental issues by partitioning posted depth into the specialist's contribution and the limit order book's (LOB) contribution. First issue we investigate is that, what affects the changes in specialists' participation strategy to the posted quotes over time in an individual stock? Specifically, do they quote according to their affirmative obligations? What are the effects of the changes in the LOB on their current quoting decisions? Do they use information from the LOB to predict the future returns of the stocks? Do they use both sides of the quotes to implement their strategies? Do they manage their inventories as inventory theories suggest? What are their reactions to the possibility of informed trading? Do the specialists increase their contribution to the

[1] For a detailed description of the specialists' functions, see Rule 104 (Dealings by Specialists) in NYSE (1999).
[2] See Harris (2003) p.494 for an extensive description of specialists' roles and how they can act against the interests of the public investors on the NYSE.

LOB when prices are volatile or when they are stable? Second, how do specialists' quoting strategies vary across stocks? Specifically, what is the effect of volume on specialists' decisions? Do the specialists quote aggressively or defensively as the price volatility increases across stocks? Is the relative tick size, as defined by the ratio of the minimum tick to stock price, important in quoting strategy of the specialists? Finally, are the participation strategies of the specialists to the posted quotes informative about direction of future price changes? How successful are the specialists in forecasting future stock returns?

The answers to these questions are very important because the information about a particular stock is disseminated to the market by specialist quotes. On the NYSE, the dollar value of average monthly trading volume that the specialists oversee was $968.18 billion and average specialist volume as percentage of the NYSE total volume was around 20% in 2004.[3] The NYSE specialists oversee this huge trading activity and there are potential conflict of interests between the specialists desire to make profits for themselves and their obligation to be fair to all public traders. There has been an important debate going on about the role of the specialists and whether their contributions are valuable in the overall trading activity. Recently, as a result of an investigation by the U.S. Securities and Exchange Commission into floor trading practices, five largest specialist firms at the New York Stock Exchange were required to pay a combined $241.8 million to settle charges of improper trading.[4] The NYSE claims that the

[3] See "Market Activity" in the NYSE fact book that can be found at http://www.nysedata.com/factbook/. Generally, the specialist participation rate mentioned in the literature is the specialist volume as percent of NYSE 2x total volume which was approximately 10% in 2004. If one wants to calculate the total volume that the specialists traded for their own accounts, specialist volume as percent of NYSE total volume is the correct figure to use.

[4] See for example, *Wall Street Journal* (October 16, 2003) "NYSE to Punish Five Specialists In Trading Inquiry".

investors get the best available price most of the time in the specialist system. However, many institutional investors prefer faster executions and believe that the human-based system for auctioning stocks does not allow this.[5] To address these concerns, the NYSE is planning to allow investors to execute more stock orders automatically.[6] Our paper directly addresses the question of whether the specialists are participating to the posted quotes in a manner consistent with their affirmative obligations.

Despite the important role played by the NYSE specialists, one can find little or no analysis of their participation strategy to the posted quotes. One reason for this lack of analysis in the previous literature is the shortage of relevant data. For a meaningful analysis of specialist behavior, one needs detailed data about orders. Publicly available TAQ database contains information about posted quotes on the NYSE. However, posted quotes reflect trading interests of the limit order traders, floor brokers, and specialists. Therefore, the mere analysis of TAQ quote changes is not sufficient to elicit information about quoting strategies of the specialists. In addition to TAQ, the NYSE provided researchers with TORQ (Trades, Orders, Reports, and Quotes) database that contains transactions, quotes, order processing data, and audit trail data for a sample of 144 stocks for three months; November 1990 through January 1991.[7] This database can be used to separate specialist contribution to quotes from those contributed by the limit order book (LOB). However, this database cannot provide much information about the current behavior, considering the numerous changes in the trading system and procedures on the

[5] See "Fidelity Urges NYSE to Revamp Trading Operation", *Wall Street Journal*, October 14, 2003.
[6] See"NYSE's Automatic Transition", *Wall Street Journal*, June 22, 2004 and NYSE Newsletter August 2004 issue on http://www.nyse.com.
[7] See Hasbrouck (1992) for a detailed description of TORQ database.

NYSE since 1991.[8] Because of the public order precedence rule, the specialist has to better the quotes in the LOB if he wants to trade. The quoting strategy of the specialists has changed considerably after the decimalization on the NYSE, because undercutting the LOB became less costly.[9]

Using 2001 NYSE system order data in the decimal pricing environment, we analyze how the specialists react to the changes in market variables while making participation decisions to the posted quotes. We define "the participation strategy of the specialists to the posted quotes" as their strategy while determining their contribution to the posted quotes in addition to the LOB. A specialist has three choices for both sides of the posted quotes. He may not participate and let the posted quotes reflect the prices and depths on the LOB (0% contribution to the posted quotes from the specialist); he may add depth to the LOB at the best prices on the book (mixed case, specialist percentage contribution is positive and less than 100%); and he may undercut the LOB which implies that the posted quotes fully reflect the trading interest of the specialist (100% contribution from the specialist). If he chooses to participate to the posted quotes, the second issue is to decide how much depth to add. We will discuss these available strategies in more detail below in the context of the empirical methodologies we employ.

Participation decision to the quotes is very important because it is a key part of the specialist's strategies. The specialist participates in quotes strategically to make profits (or avoid losses) and manage inventory by changing the probability that he participates in the upcoming trade, to fulfill obligations to provide enough depth when the depth from public limit orders is insufficient, or narrow spread when the spread from

[8] The most important change is the switch to decimal pricing. For a list of other rule changes since 1997, visit http://apps.nyse.com/commdata/PubInfoMemos.nsf/AllPubRuleChanges?openview&count=500 .
[9] See Coughenour and Harris (2003) and references therein.

public limit orders is too wide. In addition, when the specialist quotes bid and ask prices, he commits himself to trading at those prices until the next quote revision.

This work is related to a number of papers in the previous literature. Kavajecz (1999) investigates whether specialists manage quoted depth to reduce adverse selection risk. Our paper extends his analysis by formally analyzing the determinants of specialists' percentage contribution to the posted quotes. Kavajecz and Odders-White (2001) examine how specialists update the price schedules consisting of bid quotes, ask quotes, bid depths, and ask depths. Analyzing the changes in posted quotes is interesting in itself, however, as discussed above, these price schedules contain information from the LOB and the specialist does not have discretion about the portion of the price schedule changes coming from the LOB. The specialist is obliged to display the best prices and depths from the LOB if he does not quote better prices.[10] Therefore, the changes in the price schedules posted by specialists reflect the combined strategies of the limit order traders, specialist, and floor brokers, but not the specialist's contribution alone.[11] To separate the strategy of the specialist from that of the limit order traders', we have to estimate the LOB at different points in time, and calculate the net specialist contribution to the LOB depth. Madhavan and Sofianos (1998) analyze specialist participation in total transaction volume. Our analysis complements theirs by analyzing the specialists' participation to the posted quotes. Harris and Panchapagesan (2005) show that LOB is informative about future prices and that specialists use this information strategically. Our paper extends

[10] See McInish and Wood (1995) for an analysis of undisplayed limit orders on the NYSE that are at better prices than those of limit orders actually displayed.

[11] Floor brokers leave some orders with the specialist for the specialist to execute. These orders are what Sofianos and Werner (2000) call "orders passively represented by a floor broker". Posted price schedules may reflect these types of orders if there are any.

their analysis by showing directly that specialists' participation to the posted quotes also has some predictive power about future returns.

As the previous theoretical and empirical literature show, the specialists use all components of the posted price schedule, namely bid and ask prices, and bid and ask depths, while making the market for their stocks. [12] For example, if a specialist wants to sell rather than buying shares of his stock, he can decrease the probability that he will be on the buy side and increase the probability of being on the sell side of the next trade by using some combination of the following posted price schedule changes: decrease the bid and ask prices, decrease bid depth and increase ask depth that he adds to the posted quotes in addition to the LOB. However, because of his affirmative obligations, the specialist may not be able to choose a particular component of the price schedule freely. Therefore, to implement his strategy, he uses all variables in the posted price schedule, which requires that we analyze all variables in the posted quotes simultaneously. We examine the specialists' participation strategy to the posted quotes by taking the simultaneity of the bid and ask side into account.

Our results provide evidence that the specialists participate to the posted quotes in a manner, which is consistent with their affirmative obligations. Changes in the differences between best limit prices and quote midpoint are statistically and economically significant. When the difference between best limit bid (ask) price and quote midpoint increases, causing a decrease in liquidity from bid (ask) side of the LOB, specialists step in to provide additional liquidity. Other primary variables that affect the strategy of the specialists are the changes in best LOB prices and the LOB depths at those prices. Results from analyzing individual stocks over time also indicate that as volatility

[12] See Lee, Mucklow and Ready (1993), Harris (1994), and Kavajecz (1999).

increases the contribution of the specialists to the posted quotes increases indicating that they quote in a price-stabilizing manner. Specialists' participation to the posted quotes decreases by transaction volume suggesting that specialist services are needed more for low-volume stocks. The levels of specialists' participation to the posted quotes have predictive power over future stock returns. This predictive power is stronger for short-term returns. Finally, we find significant inventory effects in the discrete analysis, providing some evidence that the specialists actively manage their inventories.

The rest of the paper is organized as follows. Section 1 describes the determinants of the specialist quoting strategy as predicted by the previous literature and states the hypotheses. Section 2 describes the data. Exogenous variables that we use are discussed in section 3. Section 4 presents methodology and results for simultaneous equations analysis. Section 5 presents methodology and results for multinominal logit analysis. We discuss methods for cross sectional analysis and results in Section 6. Section 7 investigates if the participation strategies of the specialists to the posted quotes are informative about future price changes and section 8 concludes.

2. Hypotheses

2.1. The determinants of specialist participation to posted quotes over time

The specialist can consider several factors while determining his strategy. In Kyle (1985) model, the market maker revises his expectations about the value of the stock upwards (downwards) and increases (decreases) the stock price as a result of buy (sell) orders which possibly includes orders coming from informed traders. Although there are no bid and ask prices in the Kyle model, the idea is that the market maker updates his belief of what the stock is worth and adjusts the price so as to minimize his loss to

informed traders. In the context of our model, updated beliefs after a buy (sell) order will cause the specialist to increase (decrease) his contribution to the bid quotes and decrease (increase) his contribution to the ask quotes.

As first analyzed by Stoll (1978), Ho and Stoll (1981, 1983), the risk of carrying inventory is sufficient by itself to induce a positive bid-ask spread. However, many previous studies (e.g. Madhavan and Smidt (1993), Hasbrouck and Sofianos (1993), Kavajecz and Odders-White (2001)) find weak inventory effects in stocks.[13] We expect that risk averse specialist increases (decreases) his participation to the posted ask (bid) quotes when he is in long position and increases (decreases) his participation to the posted bid (ask) quotes when he is in short position.

Easley and O'Hara (1992) shows that time between trades can be correlated with the factors related to the value of the asset. In their model trade is positively correlated with the occurrence of an information event. If no trade occurs in some time interval, the market maker raises his probability that no information event has occurred. Accordingly, he moves his bid and ask closer to the true value of the stock which is between bid and ask prices. This implies that the spread will be smaller as the time between trades increases.[14] In the context of our model, we expect that as no-activity time increases, the specialist increases his contribution to the both bid and ask sides of the market.

Dupont (2000) shows that the market maker reduces depth when the volatility of the asset value is high. Intuitively, higher volatility increases the risks associated with carrying inventory which will result in less specialist contribution to depth. On the other hand, Madhavan and Sofianos (1998) state that "Price continuity rules require specialists

[13] Lyons (1998) finds strong inventory effects for a dealer in the foreign exchange market.
[14] For a similar result, see Easley, Kiefer and O'Hara (1997). For evidence of transaction clustering, see Admati and Pfleiderer (1989) and Engle and Russell (1998).

to trade to stabilize prices, suggesting that participation will be higher in stocks whose intraday return volatility is large." In a cross sectional analysis of specialist participation, they find a positive relationship between their volatility variable and the specialist participation rate. Bondarenko and Sung (2003) theoretically show that when the price volatility is high, the optimal strategy of the specialist is to increase his participation even when he is not constrained by the rules imposed by the exchange. The effect of volatility on the specialist's quoting decision is therefore an empirically open question.

The state of the LOB is an important consideration for the specialist while determining his participation to the posted quotes. During our sample period, the specialist was required to share the general information about the LOB with the floor brokers when asked.[15] However, this information was not available to most traders in the market and the specialist had considerable advantage in having exclusive access to the LOB. In Seppi (1997) model, limit order traders are the primary source of competition that the specialist faces. His model suggests that the LOB has a significant impact on the strategy of the specialist. Harris and Panchapagesan (2005) find that the specialist uses the information from the LOB in ways that favors him. They argue, for example, that an asymmetry in the LOB predicts the likely direction of future price changes. If the specialist exploits the information in the LOB, we would expect that he increases his participation to the buy (sell) side of the quotes when the LOB is heavy on the buy (sell) side to increase the probability that he buys (sells) shares of his stock.[16] On the other

[15] Recently, the NYSE started selling aggregate order book volume at each price point through its new system called the NYSE OpenBook™. The information in this system is updated every 5 seconds. This reduces but not eliminates the advantage of the specialists because they still have the exclusive access to *individual* orders. For more information, visit http://www.nysedata.com/openbook/. For the effects of the NYSE OpenBook™, see Boehmer, Saar and Yu (2003).

[16] Specialists may also use quote matching strategies. As described in Harris (2003), p.248 and p.502, quote matching is a front-running strategy in which quote matchers try to trade in front of large patient traders.

hand, if the specialist trades according to his affirmative obligations, he would increase the probability that he participates to the trade when a market buy (sell) arrives at times when the LOB is heavy on the buy (sell) side to maintain price continuity.[17] The effect of LOB variables on the specialist's participation strategy to the posted quotes is therefore an empirically open question.

As discussed in the introduction, the NYSE uses the average width of the quoted bid/ask spread, the average depth of the quotes, the number of large price reversals, and the average size of price reversals to evaluate specialists' performances. We expect that if the previous bid-ask spread is large, then the specialist will undercut the LOB in the current posted quotes (increase his percentage participation) causing the spread to be small. Similarly, if the depth that the specialist has added to the bid (ask) side in the previous quote is small, then the depth that the specialist adds to the bid (ask) side in the current quote will be large.

2.2. Cross-sectional determinants of specialist participation to posted quotes

Existing literature suggests that specialists' services are more valuable for illiquid stocks.[18] We expect that specialist participation to posted quotes should decline as the liquidity of the assigned stock increases. Trading volume can be used as a proxy for liquidity. So there should be an inverse relationship between specialist's participation and trading volume of the stock.

For example, when a quote matcher trades (buys) in front of a large buy limit order, and prices move against him, he limits his losses by trading with the standing buy limit order. When a specialist buys in a similar situation, and the prices move against him, he should not trade with the limit buy order (a negative obligation) but at least he does not need to be on the contra side of upcoming market sells until the liquidity on the buy side of the LOB is exhausted.

[17] When the specialist undercuts the LOB on one side of the market, his contribution to the posted quotes on that side of the market is 100%, i.e., his *percentage* contribution increases compared to the previous quotes, if his contribution in the previous quotes was not 100%.

[18] See for example, Grossman and Miller (1988), Glosten (1989), Huang and Liu (2004).

As discussed in the previous section in detail, when volatility is high, the specialist might reduce depth because of the risks associated with carrying inventory, or he might increase depth to stabilize the prices. Madhavan and Sofianos (1998) find a positive relationship between their volatility variable and the specialist participation rate in a cross sectional analysis of specialist participation. The effect of volatility on the specialist's participation decision to quotes is an empirically open question.

Seppi (1997) analyzes a model in which specialists face direct competition from public limit orders that have precedence under NYSE rules. He shows that specialist's profits are maximized as the tick size goes to zero. The reason is that as the tick size approaches to zero, it becomes less costly for the specialist to undercut the LOB. The tick size on the NYSE switched from eights to sixteenths on June 24, 1997 and to pennies for a number of stocks on August 28, 2000. Finally, on January 29, 2001, all stocks in NYSE started being traded in pennies.19 This decrease effectively relaxed the public order precedence rule and increased the set of prices over which the specialist can choose. As predicted by the Seppi model, Coughenour and Harris (2003) find empirically that participation rates and high frequency trading profits increased for specialists making markets for low price stocks as a result of decimalization. In the context of our model, it is more costly for the specialist to undercut the LOB for low price stocks which implies that the specialist participation to the posted quotes will be inversely related to the "Relative Tick" defined as the ratio of the minimum tick ($0.01) to the stock price.

[19] See the "trading" column in NYSE timeline at http://www.nyse.com/about/timeline/TimeLine.html.

3. Data

Our data is from the NYSE System Order Database (SOD). Because of the volume of the data, it is necessary to select a sample of NYSE-listed securities. The original sample is selected as follows: Initially, 50 most actively traded NYSE stocks during the 20 trading days prior to January 29, 2001 are chosen. In addition, 25 stocks from each of four Volume-Price groups are randomly selected. To pick the 100-stock random sample, NYSE-listed securities are ranked on share trading volume and, separately, on average NYSE trade price during the 20 trading days prior to January 29, 2001. Each security is placed into one of four categories after comparing its share price to the median NYSE share price and its trading volume to the median NYSE volume. These groups (of unequal numbers of stocks) are a high-volume:high-price group, a high-volume:low-price group, a low-volume:high-price group, and, a low-volume:low-price group. Within each group, securities are arranged alphabetically (by symbol) and every Nth security is chosen, where N is chosen to select 25 securities from that group. Because two of the 50 stocks with the highest trading volume also are randomly chosen as part of the high volume groups, the final sample has 148 securities.

NYSE's System Order Database (SOD) gives detailed information on the entry and processing of orders. Order data include security, order type, a buy-sell indicator, order size, order date and time, limit price (if the order is a limit order), and the identity of the member firm submitting the order. Execution data include the trade's date and time, the execution price, the number of shares executing, and cancellation information. Orders, executions and cancellations are time-stamped to the second.

Because of the size of the dataset, we estimated the LOBs for active stocks for one week (April 2nd ,2001 – April 6th, 2001) only. In addition, we drop 5 very active stocks. For the rest of the stocks we estimate the LOBs for three months (April 2nd, 2001 – June 29th, 2001). See Appendix A, for the symbols, and data period for each stock used in the analysis.

Since the posted quotes reflect trading interests of the limit order traders, floor brokers and the specialist, we need to estimate the LOB to separate the portion of the posted depth coming from the LOB. The LOBs are estimated by using the method described in Kavajecz (1999). First, the limit order book at the beginning of the sample period is estimated by searching for all execution and cancellation records that refer to orders placed before the sample period. Second, initial and each limit order book after that is updated sequentially depending on the placed orders, executions and cancellations. The result is the estimate of the LOBs at each point in time. After the LOBs are estimated, if the posted bid (ask) price is the same as the best limit bid (ask) price, then the LOB bid (ask) depth is subtracted from the posted bid (ask) depth. The *residual* depth comes from the specialist's trading interest and the orders left by the floor brokers with the specialist for the specialist to execute (passive floor broker participation). We call this residual as the "specialist's participation to the posted quotes".[20]

Sofianos and Werner (2000) estimate by using data from January and February 1997 that passive floor broker participation rate is 10.6% of buy plus sell volume of all purchases and sales. They also state that most orders left by floor brokers with the specialist are percentage orders. A percentage order is a limited price order to buy (or sell) 50% of the volume of a specified stock after its entry. All percentage orders have

[20] Our dataset does not allow us to split out the passive floor broker participation.

explicit price limits. Since these orders are left with the specialist (they are not *actively* represented), floor brokers do not actively react to market activity variables by changing the specification of these orders. Also when we examine the exogenous variables in section 3.1 that determine the strategy of the specialist, we can see that most of these variables (like the LOB variables) are not continuously observed by the floor brokers. Therefore, most of the systematic variation in the residual that we get after subtracting the LOB depth from posted depth should come from the reaction of the specialist to the changes in exogenous variables. Considering these facts, we assume that the residual is coming from the specialist and calculate the percentage contribution of the specialist to the posted quotes by using this residual. If one is not satisfied with this assumption, one can interpret the quoting strategy analyzed in this paper as the aggregated strategy of the NYSE floor members (specialists and floor brokers).

Table 1 provides descriptive statistics according to volume and price categories. If the average daily volume (price) of a security is above the median, then it is in the high volume (price) category, otherwise it is in the low volume (price) category. While calculating the buy and sell transaction volume, we use Lee and Ready (1991) method to classify transactions as buyer- or seller-initiated in the TAQ database of the NYSE.

We can make a couple of observations from Table 1. First, the specialist participation is higher in low-volume stocks consistent with the intuition that specialist services are needed more in thinly traded, less liquid stocks. In addition, high-volume stocks are more volatile. Finally, as expected, spreads are lower for high-volume stocks.

We also observe from Table 1 that specialist participation is higher for high-price stocks. This is consistent with the Seppi (1997) finding that, when the stock price is high,

the tick size is less important, and it is easier for the specialist to undercut the LOB. Spreads are also larger for high-price stocks. A wide spread leaves a lot of room for the specialist to undercut the LOB. This might explain high specialist participation in high-price stocks.

4. Exogenous Variables

4.1. Stock by stock analysis

We use two models that complement each other for the time series analysis of the specialist participation to posted quotes. These models are simultaneous equations model and multinominal logit model and they are discussed in more detail in Sections 4.1 and 5.1 below. To test the hypotheses discussed in the first section we use the following variables for the time series analysis. We will only discuss the liquidity provider's buy side variables, as sell side variables are similarly defined.

LOB variables.

*Change in the Best Limit Bid Price i*s the current best limit bid price minus previous best limit bid price;

Change in the Best Limit Bid Size is the current best limit bid depth minus previous best limit bid depth;

LOB Asymmetry is the total size of the sell limit orders minus total size of the buy limit orders in the LOB;

Change in the % Best Limit Bid Gap is the defined as the change in the ratio of the difference between posted quote midpoint and best limit bid price to the posted quote midpoint since the last quote revision (i.e., Δ(Midquote-Best Limit Bid)/Midquote));

(The relevant variable for sell side is *Change in the % Best Limit Ask Gap* and defined similarly; Δ(Best Limit Ask - Midquote)/Midquote));

Buy Order Placement is the sum of buy limit orders placed since the last quote revision;

Buy Cancellation Activity is the sum of buy limit orders cancelled since the last quote revision;

Other Variables.

Buy volume since the last quote revision is the total buy transaction size since the last quote revision;

Change in the Specialist's Inventory since the last quote revision. This variable is positive if the specialist has increased his inventory, i.e., he has bought more shares than he has sold, since the last quote revision;

Volatility is the coefficient of variation of the transaction prices during the last ten minutes before the current quote;

LOB idle time is the time in seconds between the last two LOB revisions;[21]

Previous Percentage Spread is the ratio of the spread to quote midpoint in the previous quotes;

Previous Posted Bid Depth is the posted bid depth in the previous quotes;

Previous Posted Ask Depth is the posted ask depth in the previous quotes.

[21] A more intuitive variable would be to use the time elapsed since the last posted quote revision. However, this variable might have the problem of being endogenous. This variable and the variable that we use are highly correlated. Nevertheless, when we included this variable in our regressions, we got qualitatively and quantitatively similar results.

4.2. Cross sectional analysis

We use the following variables to analyze how the specialists' participation decisions to posted quotes vary across stocks.

Log Mean Daily Volume is the logarithm of average daily volume over the sample period;

Log Market Capitalization is the logarithm of market capitalization as calculated by shares outstanding times stock price.

Relative Tick is the tick size (=$0.01) divided by the mean price over the sample period;

Volatility is the average of the volatility variable from the time series analysis over the sample period (see the definition in the previous section);

Average Percentage Spread is the average ratio of the spread to quote midpoint during the whole sample period for each stock.

5. Stock by stock analysis I: Simultaneous Equations Model

5.1. Methodology

As discussed in the introduction, the specialist uses all variables in the posted quotes while determining his strategy. In addition, previous literature finds that there exist asymmetric effects of the independent variables on bid and ask side of the posted quotes.[22] Accordingly, we model the revision process of the specialist participation to posted quotes as a system of two simultaneous equations, where the dependent variables are the changes in percentage specialist participation at the bid and ask since the last quote revision. Percentage specialist participation at the bid (ask) is simply the

[22] See, for example Madhavan and Smidt (1991), and Panayides (2004).

percentage of the depth that belongs to the specialist in the current total posted bid (ask) depth.

We use percentage specialist participation rather than levels of the depth that the specialist adds to the LOB because, posted quotes include four variables: bid and ask prices, and bid and ask depths. If we used levels of specialist depth only as dependent variables, it would not be possible to analyze the pricing decision of the specialist. For example, consider the following two cases:

Case 1. Posted Bid = $20, Posted Bid Depth = 200 (100 from the LOB, and 100 from the Specialist)

Case 2. Posted Bid = $20, Posted Bid Depth = 100 (100 from the Specialist only).

In both of the cases above, the specialist has 100 shares in the posted bid depth. However, in the second case, he has undercut the LOB. When we use percentage specialist participations as the dependent variables, in the first case the value of the dependent variable will be 50%, and in the second case, it will be 100%. So using the percentage contribution of the specialist to the posted quotes allows us to distinguish between the two cases above. Table 2 reports the variables and equations that are estimated by simultaneous equations model.

Identification is an important problem in estimating the simultaneous equations models. For example, to identify the coefficients in their simultaneous equations model, Kavajecz and Odders-White (2001) impose the restrictions that their bid-side (ask-side) LOB variables, the bid-side (ask-side) activity variables, and the bid-side (ask-side) regional quote variable appear only in the bid-side (ask-side) equations. In their model, 8.7% of the restrictions were rejected. However, as discussed before, it is very possible

that the specialist uses both sides of the quotes while determining his strategy and it would be natural to think that he uses exogenous variables from both sides of the market while determining his strategy. When we imposed restrictions similar to those of Kavajecz and Odders-White (2001), the rejection rate turned out to be well above 10%. Identification is not a problem in our model, because the *previous posted bid (ask) depth* variable appears only in the bid-side (ask-side) equation and the model is exactly identified. It is important to note that this is not a restriction, i.e., we do not *restrict* previous posted bid (ask) depth variable to exist only in the bid-side (ask-side) equation. Because consistent with the affirmative obligations of the specialists, we expect that if the depth that the specialist has added to the bid (ask) side in the previous quote is small, then the depth that the specialist adds to the bid (ask) side in the current quote will be large. Therefore, the depth that the specialist added to the bid (ask) side in the last posted quotes only affects his current decision of how much to add to the posted bid (ask) and accordingly previous posted bid (ask) depth variable exists only in the bid-side (ask-side) equation.

We estimated our model for each stock in our sample by using GMM and adjusted the standard errors using the Newey-West autocorrelation consistent covariance estimator.23 We used only one week of data for active stocks because of the size of the datasets. See Appendix A for the symbols, and data periods for each stock.

[23] Other methods like 2SLS or 3SLS produced similar results.

5.2. Results

The results from the simultaneous equations analysis are presented in Table 3. We report the mean and median of estimated coefficients for all stocks. The last column reports the percentage of significant coefficients at the 5% level.

Endogenous variables are negatively (positively) correlated in the bid-side (ask-side) equation. Positive coefficients imply that when specialists increase their participation on one side of the market because of their updated beliefs about the stock value, they also increase their participation to the other side of the market to support that relatively weak side of the market and to maintain price continuity.[24] Negative coefficients indicate that specialists use both sides of the market to implement their strategies. As an example, let's say that a specialist updates his beliefs about the value of the stock downwards or his inventory is above his target and he wants to decrease his inventory. He increases his participation to the ask side (to decrease his holdings of the stock), *and* he decreases his participation to the bid-side (to avoid buying the stock). For example, when the specialist's participation to the ask-side increase by 10 %, the effect of this on the bid-side is a decrease in his participation in bid side by 6.4% (0.1*0.64). The reason why he uses both the bid and ask quotes to implement his strategy when he wants to decrease his holdings might be that if he is caught with a large positive inventory when the stock prices are declining, he would suffer big losses, so price continuity motive is not very strong in this case, causing a decrease in participation to the bid-side.

[24] An increase in the percentage participation of the specialist may result from an increased percentage participation of the specialist at the quoted price, or from specialist's undercutting the LOB. The distinction between these two cases is not clear in the simultaneous equations analysis because of the definition of the endogenous variables. Multinominal logit analysis in section 5 makes this distinction in a clearer way.

On the other hand, let's say that the specialist updates his beliefs about the value of the stock upwards. Then he increases his participation to the bid-side (to increase his holdings of the stock and/or to minimize his losses to informed traders), and ask-side (to maintain price continuity). For example, when specialist's participation to the bid-side increases by 10 %, the effect of this increase on the ask-side is an increase in his participation by 10.31% (0.1*1.031). There is a strong price continuity motive in this case, because after he buys the stock, if he ends up selling the stock (because of relatively high participation to the ask-side) he only loses profit opportunities from high future prices, rather than suffering direct losses.

One of the most important players in the posted quotes is the limit order book (LOB). We use several LOB variables in our analyses. As the intuition suggests, bid-side (ask-side) LOB variables are more significant in explaining the participation of the specialists to the bid (ask) quotes, because bid-side (ask-side) LOB variables have a *direct* effect on the bid (ask) quotes. Consistent with prior expectations, specialists use all variables that they can to implement their strategies.

The specialist increases (decreases) his percentage contribution to the bid-side (ask-side) when best limit bid price increases. For example, a 1-cent increase in the best limit bid causes the specialist to increase his participation to the bid quotes by 57.77 % ($0.01 x 57.77). This implies that he uses information from the LOB, i.e., he updates his beliefs about the stock value upwards and increases (decreases) his participation to the bid-side (ask-side) to increase (decrease) the probability that he buys (sells) the stock. On the other hand, the specialist increases (decreases) his percentage contribution to the ask-

side (bid-side) when best limit ask price increases. Therefore, consistent with his affirmative obligations, he supports the relatively weak ask-side in this case.

Besides the changes in the best limit prices, changes in the sizes at those prices are significant too. When the best limit bid size increases, the specialist increases his contribution to the bid quotes. There might be two explanations. First, the specialist might update his belief about the stock value upwards and increase his participation to the posted bid quotes accordingly to increase the probability that he buys. Second, when the size at the best prices increases, the specialist can hide behind this size and safely increase his participation to the posted quotes, which improves his performance by increasing the average depth that he quotes. When the best limit ask size decreases, the specialist increases his contribution to the ask quotes to support the relatively weak ask side. However, the positive sign of the median coefficient indicates that, for most of the stocks, there is a positive relationship between the change in best limit ask size and the change in specialist participation in the ask quotes, implying that the specialist updates his belief about the stock value downwards and increase his participation to the posted ask quotes accordingly to increase the probability that he sells.

The most direct way to see if the specialists participate to the quotes in a manner consistent with their affirmative obligations is by looking at the best limit bid and ask gap variables. A large gap between best limit bid (ask) price and posted quote midpoint indicates a weak bid (ask) side that needs support from the specialist. The median of estimated coefficients for both gap variables are positive showing that when the liquidity from the LOB is not sufficient, specialists step in to provide additional liquidity. The magnitudes of the estimated coefficients are also large indicating that these “gap

variables" are two primary variables that the specialist looks at while determining his strategy.

We use some activity variables from the LOB. These variables are cumulative buy and sell order placement and cancellation since the last quote revision. Limit buy (sell) order placement variable is negative and more significant for the bid (ask) side equation indicating that, as cumulative size of limit buy (sell) orders placed increases, the specialist decreases his contribution to the bid (ask) quotes because buy-side (sell-side) of the market is strong and does not need support from the specialist. Similarly, as cumulative size of cancelled limit buy (sell) orders increases, the specialist adds more depth from his own inventory to the posted bid (ask). As a specific example, let's say that the size of cancelled buy orders since the last quote revision is 1000. This causes the specialist to increase his participation to the bid-side by 6.6% (= 1000 x 6.6 x 10^{-5}). Therefore, economic significance of the activity variables on specialists' strategy seems to be secondary when compared to changes in the best limit prices.

Harris and Panchapagesan (2005) find that an asymmetry in the LOB has significant explanatory power in predicting the future price movements. "LOB Asymmetry" variable is defined as total size of limit sell orders minus limit buy orders and measures the overall asymmetry in the LOB. When LOB asymmetry increases (because of a relative increase in limit sell orders), the specialist decreases his participation to the posted ask quote as the sign of the median coefficient indicates, because ask-side of the market is relatively strong now. This provides evidence that specialists do not try to undercut a heavy LOB on the sell-side. However, as the sign of the mean coefficient suggest, this is not true for many all specialists. The effect of the

LOB asymmetry is small though as the magnitudes of the estimated coefficients indicates.

As the volatility of the security price increases, the specialist increases (decreases) his percentage contribution in the bid (ask) sides of the quotes. This provides evidence in support of the theoretical results of the Bondarenko and Sung (2003). When the limit order depth is low as a result of high volatility, the specialist increases his contribution to the limit order book in order to stabilize prices. Estimated volatility coefficients are not positive for all stocks (not reported) however, suggesting insufficient price stabilization activity by the specialists of those stocks.

The average of estimated coefficients for "Elapsed time between the last two LOB revisions" variable is positive. This result provides evidence in favor of the finding of the Easley and O'Hara (1992) that if no activity occurs in some time interval, the market maker raises his probability that no information event has occurred. Accordingly, he increases (decreases) his participation to the bid (ask). The mean elapsed time between the last two LOB revisions is around 20 and 160 seconds for high- and low-volume stocks, respectively. A 10 minute (600 seconds) no activity time causes the specialist to increase his participation to the bid (ask) quotes by 29.88% (7.74%).

The sum of estimated coefficients of percentage bid-ask spread in the last period is positive. Bid-ask spread is an important measure of the specialist performance. Therefore, when the previous bid-ask spread is large, specialists decrease the current bid-ask spread.[25] The estimated coefficients are economically significant also. A 10% increase in percentage bid-ask spread in the previous period causes the specialist to increase

[25] Current period bid-ask spread is smaller only if the specialist increases his participation by undercutting the LOB. Multinominal Logit results below show that this is indeed the case.

(decrease) his participation to the ask (bid) quotes by 96.18% (80.87%). Hence, when the spread is large in the previous period, the specialist tries to narrow the spread by increasing his overall participation in the posted quotes.

As the posted bid (ask) depth in the previous period gets larger, the specialist adds more (less) depth to the posted bid (ask) in the current period. Therefore, if the depth in the posted bid in the previous quotes is small, the specialist increases his participation in the current bid quotes to improve his performance. The opposite is true for the ask quotes, however. One explanation might be that when the specialist wants to evaluate his own performance by looking at the ask depths he has quoted, he uses an average of posted depths that belong to many periods before the current quote.

5.2.1. Trading Volume Effects

Previous literature (e.g. Easley and et al. (1996)) finds that the specialists handle frequently traded stocks and infrequently traded stocks differently. In their analysis of posted quote changes, Kavajecz and Odders-White (2001) find that there exist significant differences between high- and low-volume stocks.

To investigate the effect of volume on the strategy of the specialist, we divide the stocks in our sample into two volume categories based on average daily volume. If the average daily volume of a stock is greater than the median, it is considered a high-volume stock; otherwise, it is a low-volume stock. The results are presented in Table 4, Panel A.

We do not find important differences between the estimated coefficients for high- and low-volume stocks in terms of significance of the coefficients. Percentages of significant variables are generally close to each other for both categories. There exist,

however, significant differences in terms of the absolute value of magnitudes of the coefficients which imply that the specialists give more weight to those variables for a particular category.

The coefficients of endogenous variables are greater in absolute value for low-volume stocks than high-volume stocks. This implies that while determining their strategies on one side of the posted quotes, the specialists of low-volume stocks place more weight to their strategies on the opposite side. One possible explanation might be that using only one side of the market to implement their strategies is not sufficient because of the low trading frequency.[26]

Changes in the LOB variables, except for the changes in best limit prices, are more important for specialists of the low-volume stocks. As suggested by Kavajecz and Odders-White (2001), one possible explanation might be that informed traders trading in low-volume stocks have less opportunities to hide their information because of the low trading activity. Therefore, they may submit limit orders instead, making the LOB more informative when compared to high-volume stocks.

Finally, the posted bid and ask depth in the previous quote has more explanatory power for the low-volume stocks. Low-volume stocks generally have a thin LOB, and need specialists' services more. Therefore, as also suggested by higher specialist participation rates to the posted quotes for low-volume stocks, posted depths on the previous quotes are more important for the specialists of low-volume stocks while making their current participation decisions.

[26] Trading frequency and trading volume are highly correlated.

5.2.2. Trading Price Effects

To investigate if the level of the price of a stock has any effects on the strategy of the specialist, we report results according to the price categories. To determine the categories, we first calculated the mean price of each stock over the sample period. If the mean price of a stock is above the median price across sample stocks, then it is in the high-price category, otherwise it is in the low-price category.

The level of transaction price can be an important consideration for the specialist while participating to the posted quotes for the following two reasons. First, when he adds depth to the LOB, for the same number of shares, he is risking more capital for high-price stocks. This is important, for example, for the inventory. The increase in the specialist's inventory of 1000 shares produces more risk for the specialist of a high-price stock than it produces for the specialist of a low-price stock. Therefore, depending on the risks that a particular change in one of the exogenous variables pose, the coefficient of that variable might have more explanatory power. Second, when the specialist wants to take a particular position in the posted quotes in *levels*, he has to add more depth to the quotes for low-price stocks when compared to the high-price stocks. This effect can lead to larger coefficients in absolute values for low-volume stocks. The results based on price categories are presented in Table 4, Panel B.

6. Stock by stock analysis II: Multinominal Logit Model

6.1. Methodology

Simultaneous equations model is powerful in the sense that it is a continuous analysis. However, specialist's decision process can be also thought to have a discrete

nature where he has to decide whether to undercut the best limit price, add depth to the LOB at the best limit price, or allow the posted quotes to fully reflect the LOB. Simultaneous equations model is not suitable for this analysis. One other potential problem with the endogenous variables in the simultaneous equations framework is that the specialist participation rates are defined as percentages, so the model does not distinguish between the *levels* added by the specialist the posted quotes. For example, the value of the dependent variable is same and equals 90% for both of the following strategies:

i. 900 shares of the 1000 shares posted on the bid side belong to the specialist,
ii. 9000 shares of the 10000 shares posted on the bid side belong to the specialist.

At first sight, these two strategies seem to be different, because in the second strategy, the *level* of the specialist's contribution to the posted quotes is large, and therefore he puts more capital at risk. However, in the second strategy, the contribution from the LOB is also large which limits the risks to the specialist because of the public order precedence rule. Therefore, it is not very clear why these two strategies might be very different. Nevertheless, the multinominal logit framework that we utilize addresses these issues. Multinominal logit incorporates the simultaneity of specialist's choices in a natural way.

A specialist faces a fundamental choice of strategy while determining his participation strategy to the posted quotes which can be thought of as a two step choice process: The first step is to decide for each side of the market whether to undercut the best limit price (Undercut: **U)**, add depth to the LOB at the best limit price (Mixed: **M**), or allow the posted quotes to fully reflect the LOB (Do not undercut: **D**). Therefore, the specialist has three choices (D, M, U) on both the bid and ask-sides for a total of nine

combinations. This decision can be seen as a *pricing decision*. Given that his decision at the first step is U or M, the second step is to decide whether to add small (**S**) or large (**L**) depth. According to this specification, the specialist has five choices (D, MS, ML, US, UL) on both sides of the market for a total of 25 combinations.

Table 5 reports the frequency distribution of the 9 strategies available to the specialist while deciding whether to undercut or add depth to LOB. We observe that, mostly, the specialists do not participate in the posted quotes, i.e., they choose the D-D strategy. In addition, given that a specialist chooses the U-strategy on one side of the market, he is more likely to choose the D strategy on the other side of the market. This implies that the specialists strategically use both side of the quotes to implement their strategies.

Table 5, Panels B and C report the frequency distribution on each side of the market according to price and volume categories. We observe from these panels that the specialists quote more aggressively for low-volume stocks. Average percentage of bid (ask) quotes in which specialists undercut the LOB for low-volume stocks is 16.24 % (17.42 %) and the respective numbers for high-volume stocks is 10.13 % (16.95 %). One reason might be that low-volume stocks have thin LOBs and they need more specialist participation. Another reason might be that it is more profitable to undercut the LOB for low-volume stocks. The specialists also quote more aggressively for high-price stocks. A possible explanation consistent with the discussion in Section 1.2 is that as the relative tick size approaches zero, it becomes less costly for the specialist to undercut the LOB.

To account for the level of depth that the specialist chooses to add, we use a multinominal logit specification that incorporates the second level decision of how much depth to add. As discussed above, we use S for small depth, and L for large depth.

Definition of "small depth" and "large depth" are stock specific. If the depth added by the specialist is greater than the median sample depth for that stock, then we classify this depth as "large", otherwise we classify it as "small". This specification implies 25 choices that are available to the specialist.[27] The problem with this specification is that, some of the 25 strategies mentioned above were never chosen by the specialists, especially for low-volume stocks. This leads to "quasi-complete separation of data points",[28] and the log-likelihood function in the multinominal logit model does not have a maximum, i.e., the maximum likelihood estimate does not exist. Normally, "quasi-complete separation of data points" is a small sample problem. But as stated in Altman, Gill and McDonald (2004), "even in large samples, it will frequently occur when there are extreme splits on the frequency distribution of either the outcome or explanatory variables". This is the case in our sample. Frequency distribution of the 25-events above (not reported) shows that, some events have frequencies that are less than 1% of the overall sample size.

To alleviate this problem, we combine the "mixed" and "undercut" strategies and call it "participate". Hence, the specialist can choose between the following strategies for both the bid- and ask-side for a total of nine combinations: do not participate (D), participate and add small depth (PS), and participate and add large depth (PL). So for example, the strategy PS-PL means that the specialist has participated and added small depth to the posted bid quotes, and he participated and added large-depth to the posted ask quotes. As another example, D-PS means that the specialist has chosen not to participate to the bid-quotes, and has participated and added small depth to the ask-quotes. Since our focus is

[27] 5 choices (D, MS, ML, US, UL) on both sides of the market for a total of 25 combinations.
[28] See chapter 10 in Altman, Gill and McDonald (2004) for details and possible solutions.

on analyzing the specialists' choice between adding levels of depth, this simplification should not be very costly. Table 6 reports detailed frequency distribution for this reduced structure.

We can make the following observations in addition to the observations from Table 5. Given that the specialist has participated, he is more likely to add small depth. Specialists participate more for low-volume stocks, and they do so by adding small depth. Similarly, they participate more for high price stocks by adding small depth to the posted quotes. General conclusion from this table is that, specialists do not participate for most of the time, and when they participate, they are more likely to add small depth.

6.2. Results

As discussed in Ellul, Holden, Jain and Jennings (2004), the exogenous variables affect the probability of choosing base case strategy, but because of the multinominal logit estimation, this effect can't be determined directly from the coefficients. In addition, occasionally, the signs of the coefficients of the non-base case variables can be different from the signs of their impact on the choices. To solve this problem, following Ellul, Holden, Jain and Jennings (2004), we calculate what they refer to as impulse sensitivities. "Impulse sensitivity" is defined as the change in the probability of an event caused by a one standard deviation increase in an explanatory variable. The benchmark probability of each event is calculated by using the estimated logistic function evaluated at the mean of each of the explanatory variables. The significance of an impulse sensitivity is calculated by the method described in Ellul, Holden, Jain and Jennings (2004).

Table 7, panel A reports the mean coefficient estimates from the multinominal analysis for the first level or pricing decisions of the specialists along with overall

significance of coefficients at the 5% levels. Overall significance rate is high, indicating that exogenous variables in our model were important for the specialists while choosing one of the 9 strategies available. Table 7, panel B reports the mean impulse sensitivities of each event. Almost all impulse sensitivities are significant at the 0.1% level. We will discuss and interpret the mean impulse sensitivities.

The percentage probability changes in a row in the impulse sensitivity tables allow us to determine how the *net* effect of a one standard deviation increase in an explanatory variable from its mean is distributed among 9 strategies available to the specialist. This distribution allows us to determine the strategies that the specialist leans towards, by looking at the overall change in predicted probabilities. It is important to note that these numbers are not *levels*, i.e., they are not overall probabilities of selecting the strategies. The average probabilities of selecting each strategy across stocks found by using the means of all exogenous variables (not reported) produce estimated probabilities close to the frequency distributions reported in Panel A of Tables 5 and 6.

An increase in the best prices in the LOB would cause the market to be stronger on the bid-side and weaker on the ask-side in terms of liquidity. This may also indicate that stock prices will increase in the future. Results in Table 7, Panel B show that, a one standard deviation increase in the best limit bid cause the specialist to increase the probability of choosing strategy M-D by 5.69 %. In addition, the probability that the specialist undercuts the LOB on the buy-side increases by 6.69%.[29] Hence, the specialist increases the probability of trading in front of a heavy limit order book on the buy-side. In contrast, when the change in the best limit ask increases by one standard deviation the highest probability increase (11.92%) belongs to the strategy D-U implying that the

[29] Sum of probability changes of the strategies U-D, U-M, and U-U.

specialist supports the sell-side of the market. The total increase in the probabilities of the strategies where the specialist undercuts the LOB on the sell-side is 28.14%.[30] These results are consistent with the fact that the specialists participate to the quotes to smooth the prices on the sell side, whereas they try to step in front of the LOB on the buy-side.[31]

Price continuity seems to be the main motivation of the specialist while reacting to the changes in the best limit prices. However, when there is an increase in LOB depth at the best price in the book, the motivation of the specialist seems to be more profit motivated. As a result of one standard deviation increase in the "change in the best limit bid (ask) size" variable, the specialist increases the probability of undercutting the LOB on the buy (sell) side by 2.24% (3.40%). Therefore, when the specialist does not have a constraint related to price smoothing, he undercuts the LOB and quotes in front of the heavy side of the LOB.

As discussed in Section 4.2, a direct way to see if the specialists participate to quotes according to their affirmative obligations is to look at the effects of changes in the difference (gap) between the best limit price and the posted quote midpoint. A large gap indicates a weak side of the market that the specialist should provide additional liquidity by stepping in. The results about "gap" variables are very strong. When one side of the market has low liquidity in the posted quotes, the specialist decreases the probability of choosing D-D strategy sharply. He increases the probability that he undercuts the LOB on the buy-side (sell-side) by 22.60% (10.99%) because of a one standard deviation shock to the bid-side (ask-side) gap variable.

[30] The strategies where the specialist undercuts the LOB on the sell-side are D-U, M-U, and U-U.
[31] Specialists do not have to make firm quotes for large sizes to maintain price continuity. For example, if there were a selling pressure and the prices would fall quickly without specialist intervention, the specialist would simply quote decreasing bid prices with bid depths that equal one round lot to smooth the prices.

We make similar observations from activity variables. Impulse sensitivity of cumulative size of cancelled buy (sell) limit orders is an increase in the probability that the specialist undercuts the LOB on the buy (sell) side by 1.03% (1.58%). As the liquidity provided by the LOB decreases, the specialist steps in to provide additional liquidity. We can also observe this by looking at the decreases in the probabilities of the D-D strategies.

Of course, specialists perform their duties only if they make at least normal profits. Otherwise, they would not provide this additional liquidity. Since the specialists have an advantage of observing the activity in the LOB, they might use this information to predict future price changes.[32] For example, when cumulative size of cancelled limit orders increases, the probability of U-U strategy increases for both the buy- and sell-side of the market. Therefore, when the specialist increases his participation on one side of the market to provide additional liquidity, he also increases his participation on opposite side of the market to hedge his position.

The impulse sensitivities for cumulative limit buy and sell order placement provides additional evidence that the specialists support the weak side of the market. As cumulative size of limit buy (sell) orders since the last quote revision increases, the probability that the specialist undercuts the LOB on the buy (sell) side decreases by 1.04% (1.14%). The effects of activity variables are small however, when compared to the effects of the changes in the best limit prices and changes in gaps between those prices and the posted quote midpoint.

If LOB asymmetry has some predictive power in predicting the future price movements and the specialists use this information, then as LOB asymmetry increases, they should increase their participation to the sell side more, relative to their participation

[32] Section 7 below analyzes this issue in more detail.

to the buy-side. We do not observe strong LOB asymmetry effects on the strategies of the specialists. Impulse sensitivities of the available strategies are all less than 1%. Analysis of Section 7 below shows that, overall asymmetry in the LOB does not have strong predictive power to forecast future price movements.

Previous literature that analyzed quote changes generally found insignificant inventory effects, possibly because they did not analyze the depth coming from the LOB and the specialist separately. We find statistically significant inventory effects. The impulse sensitivity of D-U and M-U strategies associated with the inventory variable is 0.42 % and the impulse sensitivity of U-D and U-M is -0.13 %. These impulse sensitivities are statistically significant.

One of the obligations of the specialists is to prevent large price reversals. Therefore, if the specialists are participating to posted quotes in a manner consistent with this obligation, we should see increased specialist participation during volatile periods. This is what we observe from the impulse sensitivities of the nine strategies available to the specialist. When there is a shock to the volatility by one standard deviation, the probability that the specialist undercuts the LOB on one or both sides of the market increases by 1.75%. This number indicates that there is some contribution from the specialists to decrease the volatility.

As discussed above, some of the variables that the NYSE uses to evaluate the specialist performance are the width of the quoted bid-ask spread, and average depth of the quotes. When the percentage spread in the previous quotes increases, the probability that the specialist chooses D-D strategy increases by 4.17%. Therefore, we do not find

evidence that the specialist increases probability of narrowing the spread in the current period, if the spread in the previous period was large.

We now turn to specialists' choice between adding small and large depth to the LOB and we will not discuss the impulse sensitivities of the explanatory variables for which this effect is marginal. Table 8 reports the results.

Changes in best limit prices are one of the most important variables that the specialist uses while determining his strategy. When best limit bid price increases, indicating either good news about the stock or strong buy side because of the liquidity reasons, the specialist increases his probability of choosing the D-PL strategy by 0.22%.[33] Since sell side of the market is *relatively* weak in this case, the specialist increases probability of participating and adding large depth to the ask-quotes, but this probability is smaller than the impulse sensitivity of D-D strategy associated with the change in best limit bid price. Since buy-side is relatively strong, it does not need support from the specialist. Because of an increase in the best limit ask price, the probability of the strategy D-PL increases most. When the change in best limit ask price increases by one standard deviation, the specialist increases his probability of adding large depth to the ask-quotes to provide additional liquidity. He also increases his probability of adding large depth to the bid quotes possibly because he updates his estimate of true stock value upwards.

The difference between best limit prices and midquote is an important proxy of the liquidity available in the LOB. As the liquidity in one side of the LOB is small, the specialist chooses strategies through which he increases his participation to that side of the market. However, he does not have to add large depth to maintain price continuity, so

[33] Sell side of the market is *relatively* weak in this case.

he chooses to add small depth to maintain price continuity and limit his possible losses to informed traders. This is clearly seen in Table 8, Panel B. When "Δ in the % Best Limit Bid Gap" variable increases from its mean by one standard deviation, the probability that the specialist chooses PS strategy on the buy side increases by 18.879%. When "Δ in the % Best Limit Ask Gap" variable increases from its mean by one standard deviation, the probability that the specialist chooses PL strategy on the sell side increases by 9.82%. Therefore, whenever one side of the market has insufficient liquidity, the specialist supports that side, but he does so defensively by adding small depth for the buy-side and aggressively by adding large depth for the sell-side.

We can see a similar result consistent with "affirmative obligations" of the specialist from the results about "cumulative cancelled limit buy orders" and "cumulative cancelled limit sell orders". When the cumulative size of cancelled buy (sell) limit orders increases, the buy (sell) side of the market will be *relatively* weak. Therefore, specialist's probability of choosing strategy PS for buy (sell) side increases by 1.58% (2.30%), to provide additional liquidity. As discussed above, however, he does so by adding small depth.

When the change in specialist's inventory is positive, probabilities of the strategies D-PL and D-PS increase most suggesting inventory management by the specialist. However, economic significance of these results seems to be small.

7. Cross Sectional Regression Model

7.1. Methodology

To analyze how participation of the specialists to the posted quotes varies across stocks, we estimate the following cross-sectional regression model:

$$SpecPart_i = \beta_0 + \beta_1 LogMeanDailyVol_i + \beta_2 LogMarketCap_i + \beta_3 RelTick_i + \beta_4 Volatility_i + \beta_5 AvePercSpread_i + \varepsilon_i \quad (1)$$

where, for stock i, $SpecPart_i$ is the sum of average percentage specialist participation at the bid and ask, $LogMeanDailyVol_i$ is the log of average daily volume, $LogMarketCap_i$ is the log of market capitalization, $RelTick_i$ is the tick size divided by the average stock price over the sample period, $Volatility_i$ is the average volatility of the transaction prices from the time series analysis, $AvePercSpread_i$ is the average percentage spread over the sample period and ε_i is the error term.

In equation 1, right hand side variables may not be exogenous because specialist participation to the posted quotes has some effect on these variables. Accordingly, we estimate equation 1 by using instrumental variables regression. The instruments that we use are the average of the same variables over the three months prior to the sample period.

7.2. Results

Table 9 presents the coefficient estimates of our cross sectional regression analysis. Coefficient of logarithm of mean daily volume is negative and significant. Specialist participation to posted quotes decreases as transaction volume increases. This might

indicate either that specialist services are needed more for thinly traded, illiquid stocks or participating to posted quotes for low-volume stocks is more profitable.

Another significant variable is the relative tick size. As relative tick size increases, it becomes more costly for the specialists to undercut the LOB; hence, their participation to the posted quotes decreases. In addition, there is a positive relationship between the volatility of the stock and the average percentage specialist participation providing evidence that specialists increase their participation to smooth prices for volatile stocks.

8. Are the participation strategies of the specialists to the posted quotes informative about future price changes?

By using the TORQ database, Harris and Panchapagesan (2005) show that the LOB is informative about the future price movements, and that specialists use this information while making trading decisions. During the period of TORQ database, the tick size was equal to \$1/8, and after decimalization, the strategies of the specialists have changed considerably.[34] Following Harris and Panchapagesan (2005), to investigate if the LOB is informative about future prices and specialists use this information while making participation decisions to the posted quotes, we estimate the following model by using OLS for each security i:

$$R_{i,t+k} = \alpha_i + \beta_{0,i} R_{i,t-k} + \beta_{1,i} SpBid_{i,t} + \beta_{2,i} (SpBid \times SpBidLevel)_{i,t} + \beta_{3,i} SpAsk_{i,t} + \beta_{4,i} (SpAsk \times SpAskLevel)_{i,t} + \beta_{5,i} NearLOBAsym_{i,t} + \beta_{6,i} LOBAsym_{i,t} + \varepsilon_{i,t} \quad (2)$$

where subscript t denotes posted quote time, $R_{i,t+k}$ is the transaction price return in basis points over k periods starting at time t, $R_{i,t-k}$ is the transaction price return in basis

[34] See Coughenour and Harris (2003).

points over k periods ending at time t, $SpBid_{i,t}$ is the percentage specialist participation to the posted bid at time t, $(SpBid \times SpBidLevel)_{i,t}$ is an interaction variable where $SpBidLevel$ is the amount of depth that the specialist adds to the current bid quotes, $SpAsk_{i,t}$ is the percentage specialist participation to the posted ask at time t, $(SpAsk \times SpAskLevel)_{i,t}$ is an interaction variable where $SpAskLevel$ is the amount of depth that the specialist adds to the current ask quotes, $NearLOBAsym_{i,t}$ represent the quantity asymmetry (sells-buys) in the LOB within 20 cents of the best limit prices, and $LOBAsym_{i,t}$ is the overall quantity asymmetry (sells-buys) in the LOB and $\varepsilon_{i,t}$ is the random error term. k equals 5 minutes, 1 hour or 1 day. The model captures the predictive power of the specialists' strategies and the LOB asymmetry over different time horizons. We include the lagged return to model return mean reversion in short horizon transaction price returns documented in the previous literature.

The results are reported in Table 10. A positive (negative) coefficient of $SpBid$ or $SpBid \times SpBidLevel$ ($SpAsk$ or $SpAsk \times SpAskLevel$) indicates that the specialist predicts the future return correctly. Negative coefficients of $NearLOBAsym$ and $LOBAsym$ shows that these variables are informative about future returns.

We would expect that near LOB asymmetry to the best limit prices is informative about future returns over shorter time intervals, and overall asymmetry in the LOB is informative about future returns over longer time intervals. Results show that, interestingly, the asymmetry in the LOB close to the best limit prices is informative about the future returns over both short and long time horizons. Overall asymmetry in the LOB is not very informative about future price changes.

To investigate the effect of the *level* of the depth that the specialist adds to the quotes, we use interaction variables. For example, the percentage specialist participation is 50% for both cases where the specialist has 100 shares in posted depth of 200 shares, or 5000 shares in posted depth of 10000 shares. But if the position of the specialist in the quotes is informative about future price changes, we would expect that the second case is more informative about this ability.

The signs of the interaction variables show that the overall success of specialists in predicting future returns is high. The specialists predict short-term future returns correctly for the bid-side (ask-side) for 71.22 % (82.01%) of the stocks. However, as time horizon increases, the specialists' ability to predict future returns decreases. Coefficients of interaction variables indicate that the success rate for the bid-side (ask-side) decreases to 65.47% (69.06%) for the medium-term returns and it decreases to 53.96% (58.99%) for the long-term returns.

Another observation is that the success rate of the specialists is close to the success rate of the asymmetry in the LOB close to the best limit prices. It appears that the specialists use the "near LOB asymmetry" as a source to predict short- and medium-term future price changes. The success rate of the specialists in predicting long-term price changes is not close to that of "near LOB asymmetry" possibly because, they believe that asymmetry in the LOB close to the best limit prices is short-lived and is not very useful to predict longer term returns.

9. Conclusion

We examine how the specialists react to the changes in market variables while making participation decisions to the posted quotes. We analyze the specialists' decision

to undercut or add depth to the limit order book. We distinguish between bid and ask side of the quotes. We test several hypotheses and find that the primary factor that affects the participation strategy of the specialists in the current period is the changes in the best prices and depths on the limit order book. In addition, specialists participate to the posted quotes more for low volume or high price stocks. We find significant inventory effects providing some evidence that the specialist actively manages his inventory. The levels of specialists' participation to the posted quotes have predictive power over future stock returns. This predictive power is stronger for short-term returns.

Our results indicate that on average specialists' participation to the posted quotes is consistent with their affirmative obligations, contributing to the recent debates about the usefulness of the specialist system. This is not true for all specialists, however, because there exist some heterogeneity across stocks as reflected by differences in signs and magnitudes of the estimated coefficients.

References

Admati, Anat R., and Paul Pfleiderer, 1989, Divide and Conquer: A Theory of Intraday and Day-of-the-Week Mean Effects, *Review of Financial Studies* 2, 189-223.

Altman, Micah, Jeff Gill, and Michael P. McDonald, 2004. *Numerical Issues in Statistical Computing for the Social Scientist* (John Wiley & Sons, Inc., New Jersey).

Boehmer, Ekkehart, Gideon Saar, and Lei Yu, 2003, Lifting the Veil: An Analysis of Pre-Trade Transparency at the NYSE, *NYSE working Paper* Paper #: 2003-01.

Bondarenko, Oleg, and Jaeyoung Sung, 2003, Specialist participation and limit orders, *Journal of Financial Markets* 6, 539-571.

Coughenour, Jay F., and Lawrence E. Harris, 2003, Specialist Profits and Minimum Price Increment, *Working Paper, University of Delaware*.

Dupont, Dominique, 2000, Market Making, Prices, and Quantity Limits, *Review of Financial Studies* 13, 1129-51.

Easley, David, and et al., 1996, Liquidity, Information, and Infrequently Traded Stocks, *Journal of Finance* 51, 1405-36.

Easley, David, Nicholas M. Kiefer, and Maureen O'Hara, 1997, One Day in the Life of a Very Common Stock, *Review of Financial Studies* 10, 805-35.

Easley, David, and Maureen O'Hara, 1992, Time and the Process of Security Price Adjustment, *Journal of Finance* 47, 576-605.

Ellul, Andrew, Craig W. Holden, Pankaj Jain, and Robert Jennings, 2004, A Comprehensive Test of Order Choice Theory: Recent Evidence from the NYSE, *Working Paper, Indiana University*.

Engle, Robert F., and Jeffrey R. Russell, 1998, Autoregressive Conditional Duration: A New Model for Irregularly Spaced Transaction Data, *Econometrica* 66, 1127-62.

Glosten, Lawrence R., 1989, Insider Trading, Liquidity, and the Role of the Monopolist Specialist, *Journal of Business* 62, 211-35.

Grossman, Sanford J., and Merton H. Miller, 1988, Liquidity and Market Structure, *Journal of Finance* 43, 617-37.

Harris, Larry, 2003. *Trading and Exchanges: Market Microstructure for Practitioners* (Oxford University Press).

Harris, Lawrence E., 1994, Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes, *Review of Financial Studies* 7, 149-78.

Harris, Lawrence E., and Venkatesh Panchapagesan, 2005, The information content of the limit order book: evidence from NYSE specialist trading decisions, *Journal of Financial Markets* 8, 25-67.

Hasbrouck, Joel, 1992, Using the TORQ Database, *Working Paper, New York University*.

Hasbrouck, Joel, and George Sofianos, 1993, The Trades of Market Makers: An Empirical Analysis of NYSE Specialists, *Journal of Finance* 48, 1565-93.

Ho, Thomas S. Y., and Hans R. Stoll, 1983, The Dynamics of Dealer Markets under Competition, *Journal of Finance* 38, 1053-74.

Ho, Thomas, and Hans R. Stoll, 1981, Optimal Dealer Pricing under Transactions and Return Uncertainty, *Journal of Financial Economics* 9, 47-73.

Huang, Roger D., and Jerry W. Liu, 2004, Do Individual NYSE Specialists Subsidize Illiquid Stocks?, *University of Notre Dame, Working Paper.*

Kavajecz, Kenneth A., 1999, A Specialist's Quoted Depth and the Limit Order Book, *Journal of Finance* 54, 747-71.

Kavajecz, Kenneth A., and Elizabeth R. Odders-White, 2001, An Examination of Changes in Specialists' Posted Price Schedules, *Review of Financial Studies* 14, 681-704.

Kyle, Albert S., 1985, Continuous Auctions and Insider Trading, *Econometrica* 53, 1315-35.

Lee, Charles M. C., Belinda Mucklow, and Mark J. Ready, 1993, Spreads, Depths, and the Impact of Earnings Information: An Intraday Analysis, *Review of Financial Studies* 6, 345-74.

Lee, Charles M. C., and Mark J. Ready, 1991, Inferring Trade Direction from Intraday Data, *Journal of Finance* 46, 733-46.

Lyons, Richard K., 1998, Profits and Position Control: A Week of FX Dealing, *Journal of International Money and Finance* 17, 97-115.

Madhavan, Ananth, and Seymour Smidt, 1991, A Bayesian Model of Intraday Specialist Pricing, *Journal of Financial Economics* 30, 99-134.

Madhavan, Ananth, and Seymour Smidt, 1993, An Analysis of Changes in Specialist Inventories and Quotations, *Journal of Finance* 48, 1595-1628.

Madhavan, Ananth, and George Sofianos, 1998, An Empirical Analysis of NYSE Specialist Trading, *Journal of Financial Economics* 48, 189-210.

McInish, Thomas H., and Robert A. Wood, 1995, Hidden Limit Orders on the NYSE, *Journal of Portfolio Management* 21, 19-26.

NYSE, 1999. *New York Stock Echange, INC. Constitution and Rules* (CCH Incorporated, Chicago, IL).

Panayides, Marios, 2004, The Specialist's Participation in Quoted Prices and the NYSE's Price Continuity Rule, *Working Paper, Yale University*.

Seppi, Duane J., 1997, Liquidity Provision with Limit Orders and a Strategic Specialist, *Review of Financial Studies* 10, 103-50.

Sofianos, George, and Ingrid M. Werner, 2000, The trades of NYSE floor brokers, *Journal of Financial Markets* 3, 139-176.

Stoll, Hans R., 1978, The Supply of Dealer Services in Securities Markets, *Journal of Finance* 33, 1133-51.

Tables

Table 1. Descriptive Statistics
This Table provides descriptive statistics according to volume and price categories. Prices are denominated in dollars and quantities are denominated in shares.

	Volume Categories		High	Price Categories	
Variable	**Mean**	**Std**	**Low**	**Mean**	**Std**
% Spec. Partc. to the posted bid	0.17	0.35	H	0.20	0.37
	0.21	0.39	L	0.18	0.36
% Spec. Partc. to the posted ask	0.28	0.41	H	0.30	0.42
	0.23	0.40	L	0.22	0.39
Δ % Spec. Partc. to the posted bid	0.00	0.32	H	0.00	0.35
	0.00	0.34	L	0.00	0.31
Δ % Spec. Partc. to the posted ask	0.00	0.35	H	0.00	0.37
	0.00	0.34	L	0.00	0.32
Δ Best Limit Bid Price	0.00	0.07	H	0.00	0.10
	0.00	0.11	L	0.00	0.07
Δ Best Limit Ask Price	0.00	0.11	H	0.00	0.14
	0.00	0.15	L	0.00	0.12
Δ Best Limit Bid Size	-2.88	16,614.03	H	-1.10	10,936.32
	-2.18	12,961.90	L	-4.08	18,549.77
Δ Best Limit Ask Size	-5.53	19,326.72	H	-1.42	14,337.03
	-3.26	17,320.76	L	-7.76	21,914.47
Δ % Best Limit Bid Gap	0.00	0.00	H	0.00	0.00
	0.00	0.01	L	0.00	0.00
Δ % Best Limit Ask Gap	0.00	0.00	H	0.00	0.00
	0.00	0.01	L	0.00	0.01
Buy Order Placement	1,459.74	9,454.57	H	1,191.88	7,137.33
	576.26	7,110.37	L	1,019.12	9,825.96
Sell Order Placement	1,476.89	10,132.47	H	1,181.04	7,418.98
	561.63	7,705.13	L	1,038.43	10,738.19
Buy Cancellation Activity	698.21	5,721.43	H	589.67	4,419.06
	407.80	6,833.60	L	573.48	7,539.85
Sell Cancellation Activity	726.91	5,625.20	H	602.75	4,646.92
	392.02	7,511.39	L	582.11	7,828.35
Change in LOB Asymmetry	19.55	26,216.60	H	3.40	16,973.67
	-17.58	19,651.96	L	5.93	28,990.23
Buy volume since the last quote revision	1,097.27	13,365.79	H	892.91	11,610.94
	145.67	3,237.60	L	540.10	9,387.55
Sell volume since the last quote revision	1,205.64	43,186.57	H	965.07	40,859.35
	147.04	10,591.51	L	598.81	25,725.35
Change in Specialist's Inventory	0.87	2,790.03	H	0.23	2,485.12
	-1.23	920.67	L	-0.17	1,959.70
Time between consecutive LOB revisions in seconds	21.82	68.23	H	53.70	1,564.07
	161.61	2,991.16	L	101.54	2,171.94
Volatility	0.20	0.26	H	0.13	0.19
	0.09	0.18	L	0.17	0.28
Spread in cents	6.40	28.25	H	7.91	31.56
	9.67	29.50	L	7.53	25.80
Posted Bid Depth	3,067.97	9,150.06	H	2,483.12	8,067.23
	1,598.55	12,591.81	L	2,475.40	12,748.40
Posted Ask Depth	4,032.43	10,185.39	H	3,109.35	7,917.32
	1,925.43	12,690.81	L	3,265.76	13,846.58

Table 2. Equations that are estimated by simultanous equations model

	Endogoneous Variables	
Explanatory Variables	**Change in % Specialist Participation at the Bid**	**Change in % Specialist Participation at the Ask**
Intercept	X	X
Δ in % Spec. Partc. at the Bid		X
Δ in % Spec. Partc. at the Ask	X	
Δ in the Best Limit Bid Price	X	X
Δ in the Best Limit Ask Price	X	X
Δ in the Best Limit Bid Size	X	X
Δ in the Best Limit Ask Size	X	X
Δ in the % Best Limit Bid Gap	X	X
Δ in the % Best Limit Ask Gap	X	X
Δ in the LOB Asymmetry	X	X
Cumulative Limit Buy Order Placement	X	X
Cumulative Limit Sell Order Placement	X	X
Cumulative Cancelled Limit Buy Orders	X	X
Cumulative Cancelled Limit Sell Orders	X	X
Elapsed time between last two LOB revisions	X	X
Volatility	X	X
Buy volume since the last quote revision	X	X
Sell volume since the last quote revision	X	X
Δ in the Specialist's Inventory	X	X
Previous Percentage Spread	X	X
Previous Posted Bid Depth	X	
Previous Posted Ask Depth		X

X indicates a right hand side variable included in the relevant equation.

Table 3. Simultaneous Equations Model Results for stock by stock estimation

For each explanatory variable in each equation, the mean and median of all coefficient estimates across the stocks in the sample are provided. % column reports the percentage of significant coefficients at the 5% level. All numbers for explanatory variables with a * are multiplied by 100000.

	Equations					
	Δ in % Spec. Partc. at the Bid			Δ in % Spec. Partc. at the Ask		
Exogenous variables	**Mean**	**Median**	**5%**	**Mean**	**Median**	**5%**
Intercept	0.026	-0.024	50.360	-0.040	-0.012	30.935
Δ in % Spec. Partc. at the Bid				1.031	0.304	16.547
Δ in % Spec. Partc. at the Ask	-0.640	0.028	12.230			
Δ in the Best Limit Bid Price	57.770	0.790	25.899	-15.125	-4.519	37.410
Δ in the Best Limit Ask Price	-56.220	-1.047	28.058	14.596	3.731	36.691
Δ in the Best Limit Bid Size*	0.674	0.020	47.482	9.500	-0.034	13.669
Δ in the Best Limit Ask Size*	3.200	-0.033	10.072	-1.000	0.024	58.273
Δ in the % Best Limit Bid Gap	1,848.011	100.662	35.252	-651.671	-211.751	47.482
Δ in the % Best Limit Ask Gap	1,467.203	-29.090	29.496	-299.060	25.469	33.813
Δ in the LOB Asymmetry*	0.552	0.065	22.302	0.635	-0.176	49.640
Cumulative Limit Buy Order Placement*	-2.000	-0.223	24.460	-6.000	-0.005	12.950
Cumulative Limit Sell Order Placement*	3.200	-0.020	7.914	-4.000	-0.106	23.741
Cumulative Cancelled Limit Buy Orders*	6.600	0.683	44.604	1.300	0.062	11.511
Cumulative Cancelled Limit Sell Orders*	15.700	0.138	5.755	5.300	0.321	30.935
Elapsed time between last two LOB revisions*	49.800	0.589	27.338	12.900	0.419	15.827
Volatility	0.890	-0.013	15.108	-0.009	-0.003	7.194
Buy volume since the last quote revision*	-1.000	-0.072	11.511	2.900	0.000	19.424
Sell volume since the last quote revision*	3.300	0.010	7.914	11.500	-0.068	14.388
Δ in the Specialist's Inventory*	1.700	-0.022	7.914	-0.243	0.080	10.072
Previous Percentage Spread	-8.087	3.863	44.604	9.618	2.141	25.899
Previous Posted Bid Depth*	-0.958	0.127	35.971			
Previous Posted Ask Depth*				0.675	0.031	40.288

Table 4. Simultaneous Equations Model Results for stock by stock estimation by trading volume and price categories

For each explanatory variable in each equation, the mean of all coefficient estimates across the stocks in the sample are provided. 1% and 5% columns report the percentage of significant coefficients at the 1% and 5% levels, respectively. All coefficient estimates for explanatory variables with a * are multiplied by 100000. Prices are denominated in dollars and quantities are denominated in shares.

Panel A. Volume Categories

		Equations					
		Δ in % Spec. Partc. at the bid			Δ in % Spec. Partc. at the ask		
Exogenous variables	**Cat.**	**Mean**	**Median**	**5%**	**Mean**	**Median**	**5%**
Intercept	H	0.00	-0.02	40.00	-0.02	-0.01	22.86
	L	0.05	-0.03	60.87	-0.06	-0.02	39.13
Δ in % Spec. Partc. at the Bid	H				-0.11	0.37	14.29
	L				2.18	0.19	18.84
Δ in % Spec. Partc. at the Ask	H	0.53	-0.13	10.00			
	L	-1.83	0.12	14.49			
Δ in the Best Limit Bid Price	H	97.79	1.35	14.29	-21.95	-8.16	42.86
	L	17.17	0.51	37.68	-8.20	-0.36	31.88
Δ in the Best Limit Ask Price	H	-94.83	-1.30	15.71	21.26	7.22	40.00
	L	-17.05	-0.68	40.58	7.84	-0.55	33.33
Δ in the Best Limit Bid Size*	H	0.08	-0.06	42.86	-0.40	-0.01	7.14
	L	1.30	0.13	52.17	19.60	-0.08	20.29
Δ in the Best Limit Ask Size*	H	0.69	-0.03	4.29	-0.13	-0.10	58.57
	L	5.70	-0.04	15.94	-3.00	0.35	57.97
Δ in the % Best Limit Bid Gap	H	3,248.18	125.53	27.14	-968.43	-722.59	55.71
	L	427.55	42.80	43.48	-330.32	-41.18	39.13
Δ in the % Best Limit Ask Gap	H	2,484.91	-42.61	20.00	-569.29	7.05	31.43
	L	434.74	-28.95	39.13	-24.92	41.79	36.23
Δ in the LOB Asymmetry*	H	0.30	0.04	22.86	-0.20	-0.15	52.86
	L	0.81	0.11	21.74	1.50	-0.22	46.38
Cumulative Limit Buy Order Placement*	H	0.23	-0.09	15.71	-0.07	-0.04	12.86
	L	-5.00	-0.48	33.33	-11.00	0.11	13.04
Cumulative Limit Sell Order Placement*	H	-0.36	-0.07	8.57	-0.08	-0.04	7.14
	L	6.80	0.14	7.25	-7.00	-0.96	40.58
Cumulative Cancelled Limit Buy Orders*	H	0.35	0.26	30.00	0.56	0.07	15.71
	L	13.00	2.70	59.42	2.00	-0.02	7.25
Cumulative Cancelled Limit Sell Orders*	H	0.62	0.11	5.71	0.16	0.05	14.29
	L	30.90	0.20	5.80	10.40	4.10	47.83
Elapsed time between last two LOB revisions*	H	97.10	32.10	27.14	25.00	19.70	12.86
	L	1.80	0.04	27.54	0.66	0.09	18.84
Volatility	H	-0.01	-0.02	20.00	-0.01	0.00	10.00
	L	1.80	-0.01	10.15	0.00	0.00	4.35
Buy volume since the last quote revision*	H	-0.38	-0.05	10.00	-0.22	-0.02	24.29
	L	-2.00	-0.14	13.04	6.10	0.13	14.49
Sell volume since the last quote revision*	H	0.27	-0.01	7.14	-0.11	-0.06	17.14
	L	6.30	0.14	8.70	23.30	-0.10	11.59
Δ in the Specialist's Inventory*	H	0.23	0.06	5.71	0.30	-0.02	8.57
	L	3.10	-0.10	10.15	-0.80	0.29	11.59
Previous Percentage Spread	H	-10.98	8.29	44.29	15.01	3.47	22.86
	L	-5.15	2.71	44.93	4.14	0.97	28.99
Previous Posted Bid Depth*	H	0.03	0.04	28.57			
	L	-2.00	0.47	43.48			
Previous Posted Ask Depth*	H				0.01	-0.03	25.71
	L				1.30	0.44	55.07

Table 4. cont'd

Panel B. Price Categories

		Equations					
		Δ in % Spec. Partc. at the bid			Δ in % Spec. Partc. at the ask		
Exogenous variables	**Cat.**	**Mean**	**Median**	**5%**	**Mean**	**Median**	**5%**
Intercept	H	0.00	-0.02	43.48	-0.06	-0.01	28.99
	L	0.05	-0.03	57.14	-0.02	-0.01	32.86
Δ in % Spec. Partc. at the Bid	H				1.90	0.26	14.49
	L				0.18	0.30	18.57
Δ in % Spec. Partc. at the Ask	H	1.19	0.03	14.49			
	L	-2.44	0.03	10.00			
Δ in the Best Limit Bid Price	H	111.27	0.61	21.74	-29.39	-10.24	40.58
	L	5.03	1.87	30.00	-1.06	-2.99	34.29
Δ in the Best Limit Ask Price	H	-106.77	-0.91	24.64	29.13	10.69	39.13
	L	-6.39	-1.75	31.43	0.27	2.67	34.29
Δ in the Best Limit Bid Size*	H	0.39	-0.01	53.62	19.30	-0.07	17.39
	L	0.95	0.03	41.43	-0.17	-0.02	10.00
Δ in the Best Limit Ask Size*	H	1.00	-0.06	10.15	-3.00	-0.09	62.32
	L	5.30	-0.02	10.00	0.06	0.07	54.29
Δ in the % Best Limit Bid Gap	H	3,501.51	165.22	28.99	-1,264.17	-802.97	49.28
	L	218.14	57.52	41.43	-47.92	-73.95	45.71
Δ in the % Best Limit Ask Gap	H	2,648.45	-111.53	28.99	-746.67	2.88	27.54
	L	302.84	-21.89	30.00	142.16	29.42	40.00
Δ in the LOB Asymmetry*	H	0.36	0.12	26.09	1.80	-0.22	52.17
	L	0.74	0.02	18.57	-0.53	-0.11	47.14
Cumulative Limit Buy Order Placement*	H	-0.33	-0.20	26.09	-11.00	-0.04	13.04
	L	-4.00	-0.31	22.86	-0.12	0.01	12.86
Cumulative Limit Sell Order Placement*	H	-0.70	-0.07	10.15	-6.00	-0.10	17.39
	L	7.10	0.00	5.71	-1.00	-0.17	30.00
Cumulative Cancelled Limit Buy Orders*	H	3.20	0.62	40.58	2.00	0.06	13.04
	L	10.00	0.73	48.57	0.57	0.06	10.00
Cumulative Cancelled Limit Sell Orders*	H	1.40	0.17	5.80	6.20	0.21	30.44
	L	29.70	0.10	5.71	4.40	0.73	31.43
Elapsed time between last two LOB revisions*	H	49.80	0.38	20.29	21.20	0.98	13.04
	L	49.80	1.10	34.29	4.70	0.13	18.57
Volatility	H	0.01	-0.03	17.39	-0.04	0.00	5.80
	L	1.76	-0.01	12.86	0.03	0.00	8.57
Buy volume since the last quote revision*	H	-0.09	-0.05	10.15	5.50	0.00	15.94
	L	-2.00	-0.11	12.86	0.33	0.00	22.86
Sell volume since the last quote revision*	H	1.20	0.04	8.70	22.70	-0.08	10.15
	L	5.30	-0.01	7.14	0.55	-0.03	18.57
Δ in the Specialist's Inventory*	H	0.25	0.05	5.80	-1.00	0.00	5.80
	L	3.00	-0.07	10.00	0.55	0.13	14.29
Previous Percentage Spread	H	-13.17	6.13	39.13	17.32	3.50	23.19
	L	-3.08	3.41	50.00	2.03	1.16	28.57
Previous Posted Bid Depth*	H	1.10	0.10	28.99			
	L	-3.00	0.17	42.86			
Previous Posted Ask Depth*	H				0.96	0.02	33.33
	L				0.40	0.06	47.14

Table 5. Percentage participation by the NYSE specialists to the posted quotes

This table reports the percentage of bid side and ask side participation decisions of the specialists for 38 stocks in the current sample according to volume and price categories. The pricing decisions are D (Don't Participate to the Posted Quotes; no specialist depth), M (Add Depth to the Limit Order Book; mixed), and U (Undercut the Limit Order Book; specialist alone). If mean daily volume (mean price) of a stock is higher than the median, then it is in "high" category, otherwise it is in "low" category. The numbers in the rows sum up to 100%.

Panel A.

Bid Side Choice	Ask Side Choice			Total
	D	M	U	
D	52.33	11.06	12.12	75.51
M	7.00	2.77	2.14	11.91
U	7.79	1.92	2.88	12.59
Total	67.12	15.74	17.14	100

Panel B.

Volume Categories	D (LOB Alone)	M (LOB+Specialist)	U (Specialist Alone)
Bid-Side of the posted quotes			
High	75.60	14.27	10.13
Low	75.37	8.39	16.24
Ask-Side of the posted quotes			
High	63.87	19.18	16.95
Low	71.96	10.62	17.42

Panel C.

Price Categories	D (LOB Alone)	M (LOB+Specialist)	U (Specialist Alone)
Bid-Side of the posted quotes			
High	73.42	13.46	13.11
Low	77.55	10.38	12.07
Ask-Side of the posted quotes			
High	61.91	18.56	19.53
Low	72.23	12.98	14.79

Table 6. Percentage participation by the NYSE specialists to the posted quotes in levels

The decisions are D (Don't Participate to the Posted Quotes; no specialist depth), PL (Participate and add large depth), and PS (Participate and add small depth). If mean daily volume (mean price) of a stock is higher than the median, then it is in "high" category, otherwise it is in "low" category. In Panel A, for a particular strategy, reported two numbers are frequency and percent of total. In Panel B, values reported are row percentages that sum up to 100% subject to rounding.

Panel A.

Specialist Strategies

Posted Bid	Posted Ask			Total
	D	PL	PS	
D	52.32	10.66	12.53	75.51
PL	6.59	2.01	2.2	10.8
PS	8.22	2.17	3.3	13.69
Total	67.13	14.84	18.03	100

Panel B.

Volume Categories	D	PL	PS
Bid-Side of the posted quotes			
High	75.59	11.44	12.96
Low	75.37	9.81	14.82
Ask-Side of the posted quotes			
High	64.03	17.05	18.92
Low	71.96	11.4	16.64

Price Categories	D	PL	PS
Bid-Side of the posted quotes			
High	73.42	12.04	14.54
Low	77.45	9.65	12.89
Ask-Side of the posted quotes			
High	61.91	17.34	20.75
Low	72.01	12.5	15.49

Table 7. Multinominal Logit Model Results for stock by stock estimation

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Strategies of the specialist for both sides of the posted quotes are defined as follows: D-Do not undercut the LOB; M (Mixed)-add depth to the LOB at the best limit price; and U-Undercut the best limit price. Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns reports the percentage of significant variables at the stated levels of significance. Impulse sensitivities reported in Panel B are significant at the 0.1% level. All coefficient estimates for explanatory variables with a * are multiplied by 100000.

Panel A. Mean Regression Coefficient Estimates

	9 Choices Available to the Specialist (D-D is the base case)								Overall Significance (%)	
Exogenous Variables	**D-M**	**D-U**	**M-D**	**M-M**	**M-U**	**U-D**	**U-M**	**U-U**	**1% sig.**	**5% sig.**
Δ in the Best Limit Bid Price	4.19	-62.79	12.77	12.70	-76.57	-4.81	2.22	-51.98	58.62	77.01
Δ in the Best Limit Ask Price	-12.40	58.26	-10.11	-16.11	75.49	-0.12	-10.73	44.29	58.62	72.41
Δ in the Best Limit Bid Size*	-0.20	-0.09	-2.88	-2.90	-2.64	1.68	1.54	1.57	72.41	80.46
Δ in the Best Limit Ask Size*	-1.41	1.35	0.12	-1.65	1.04	0.03	-1.40	1.18	62.07	67.82
Δ in the % Best Limit Bid Gap	81.63	-3465.20	24.15	160.47	-3831.14	1347.08	1702.90	-948.97	80.46	90.80
Δ in the % Best Limit Ask Gap	-27.31	-523.85	423.93	319.98	-931.26	-797.38	-442.64	-1379.89	60.92	67.82
Δ in the LOB Asymmetry*	-0.55	-0.50	0.46	-0.05	-0.04	0.10	-0.31	-0.40	35.63	51.72
Cumulative Limit Buy Order Placement*	-2.08	-0.16	-1.81	-4.59	-1.89	-4.21	-12.05	-3.00	18.39	39.08
Cumulative Limit Sell Order Placement*	-1.81	-6.81	-0.81	-4.56	-9.25	0.09	-3.73	-7.92	19.54	31.03
Cumulative Cancelled Limit Buy Orders*	-3.46	0.63	0.22	-11.19	-4.05	4.86	1.56	5.24	36.78	49.43
Cumulative Cancelled Limit Sell Orders*	0.24	7.62	-3.47	-37.58	5.10	1.34	-12.57	7.51	28.74	35.63
Elapsed time between last two LOB revisions*	124.07	-335.36	293.55	341.11	-94.03	-278.57	-211.00	-0.01	59.77	71.26
Volatility	-0.08	0.85	-0.41	-0.97	0.44	0.18	0.19	1.37	90.80	94.25
Buy volume since the last quote revision*	-3.86	0.18	-0.57	-11.10	-3.76	-1.85	-4.31	-2.48	20.69	31.03
Sell volume since the last quote revision*	-2.08	-0.30	-3.22	-8.01	-3.27	-1.38	-4.37	-4.50	16.09	27.59
Δ in the Specialist's Inventory*	0.93	3.19	0.14	1.62	-1.78	-1.35	-0.46	0.88	18.39	31.03
Previous % Spread	-263.80	-128.76	-68.14	-349.00	-175.27	75.25	-109.45	14.62	100.00	100.00
Previous Posted Bid Depth*	1.25	2.68	4.60	3.71	4.96	-18.40	-20.25	-19.17	98.85	100.00
Previous Posted Ask Depth*	5.53	-7.61	-0.46	4.62	-7.42	1.51	5.57	-6.91	97.70	100.00

Table 7. cont'd

Panel B. Mean Impulse Sensitivites (%)

	9 Choices Available to the Specialist								
Exogoneous Variables	**D-D**	**D-M**	**D-U**	**M-D**	**M-M**	**M-U**	**U-D**	**U-M**	**U-U**
Δ in the Best Limit Bid Price	-9.17	-0.69	-6.57	5.69	5.02	-0.97	1.36	3.57	1.76
Δ in the Best Limit Ask Price	-24.05	-3.88	11.92	-2.41	0.86	6.94	0.50	0.83	9.28
Δ in the Best Limit Bid Size	0.51	0.28	0.09	-1.09	-0.54	-0.36	0.74	0.14	0.23
Δ in the Best Limit Ask Size	-0.10	-0.89	1.02	0.24	-0.44	0.14	-0.05	-0.18	0.26
Δ in the % Best Limit Bid Gap	-13.13	-1.14	-9.48	0.64	2.31	-1.81	11.10	8.27	3.24
Δ in the % Best Limit Ask Gap	-15.32	-1.85	4.45	2.86	3.36	2.30	-1.21	1.18	4.24
Δ in the LOB Asymmetry	0.64	-0.76	-0.53	0.51	0.05	0.01	0.14	0.00	-0.07
Cumulative Limit Buy Order Placement	1.10	0.00	0.50	-0.30	-0.28	0.01	-0.65	-0.28	-0.11
Cumulative Limit Sell Order Placement	0.81	0.16	-0.58	0.08	-0.13	-0.27	0.26	-0.05	-0.29
Cumulative Cancelled Limit Buy Orders	-0.37	-0.65	0.04	0.10	-0.15	0.01	0.72	0.04	0.27
Cumulative Cancelled Limit Sell Orders	-1.37	0.25	1.20	-0.38	-0.10	0.12	0.01	0.01	0.26
Elapsed time between last two LOB revisions	0.54	0.17	-0.42	0.05	0.14	-0.08	-0.07	-0.12	-0.20
Volatility	-0.82	-0.15	1.12	-0.49	-0.29	0.10	0.12	0.03	0.39
Buy volume since the last quote revision	1.04	-0.73	0.13	0.13	-0.22	-0.08	-0.14	-0.17	0.03
Sell volume since the last quote revision	-0.43	-1.14	-0.25	-0.01	-0.57	-0.05	0.74	0.34	1.38
Δ in the Specialist's Inventory	-0.33	0.12	0.41	-0.10	0.02	0.02	-0.11	-0.03	0.01
Previous % Spread	4.17	-4.07	-1.39	-0.19	-0.86	-0.20	1.65	0.04	0.86
Previous Posted Bid Depth	-0.99	1.73	1.14	1.16	0.25	0.36	-2.27	-0.63	-0.76
Previous Posted Ask Depth	-3.78	3.98	-0.93	-0.07	0.54	-0.33	0.26	0.81	-0.49

Table 8. Multinominal Logit Model Results for stock by stock estimation

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Strategies of the specialist for both sides of the posted quotes are defined as follows: D-Do not participate; PS (PL)- Participate and add small (large) depth. Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns reports the percentage of significant variables at the stated levels of significance. Impulse sensitivities reported in Panel B are significant at the 0.1% level. All coefficient estimates for explanatory variables with a * are multiplied by 100000.

Panel A. Mean Regression Coefficient Estimates

	9 Choices Available to the Specialist (D-D is the base case)								Overall Significance (%)	
Exogenous Variables	**D-PS**	**D-PL**	**PS-D**	**PS-PS**	**PS-PL**	**PL-D**	**PL-PS**	**PL-PL**	**1% sig.**	**5% sig.**
Δ in the Best Limit Bid Price	-32.15	-24.33	5.00	-40.02	-1.59	-4.73	-35.60	-18.52	56.38	70.21
Δ in the Best Limit Ask Price	29.13	13.32	-5.72	36.89	-7.24	3.08	32.61	8.30	53.19	61.70
Δ in the Best Limit Bid Size*	-0.16	0.03	0.34	0.29	0.13	-0.22	-0.12	-0.71	57.45	68.09
Δ in the Best Limit Ask Size*	0.68	0.63	-0.09	0.43	0.79	0.30	0.44	0.32	57.45	64.89
Δ in the % Best Limit Bid Gap	-1503.65	-1614.04	736.99	-1017.46	310.49	410.75	-953.89	-706.61	74.47	76.60
Δ in the % Best Limit Ask Gap	-285.13	-382.81	-184.02	-1107.57	128.17	-322.33	-572.13	-510.36	46.81	58.51
Δ in the LOB Asymmetry*	-0.33	-0.88	0.38	-0.06	-0.77	0.27	0.09	-0.48	50.00	58.51
Cumulative Limit Buy Order Placement*	-0.45	-0.33	-8.77	-7.51	-15.91	-4.37	-6.18	-5.65	32.98	48.94
Cumulative Limit Sell Order Placement*	-10.69	-1.40	-0.37	-13.31	-6.66	0.17	-9.88	-2.84	36.17	46.81
Cumulative Cancelled Limit Buy Orders*	0.27	-0.26	12.77	9.68	12.65	0.29	-4.40	-2.69	37.23	51.06
Cumulative Cancelled Limit Sell Orders*	15.78	0.46	-0.15	13.67	-7.07	1.53	14.82	-2.91	30.85	47.87
Elapsed time between last two LOB revisions*	-25.82	16.29	35.57	-96.07	-90.31	203.82	88.26	136.91	50.00	60.64
Volatility	0.29	0.70	-0.05	0.41	0.56	0.05	0.20	0.85	92.55	95.74
Buy volume since the last quote revision*	-3.59	0.76	-7.55	-10.00	-7.43	2.51	-4.08	1.02	36.17	47.87
Sell volume since the last quote revision*	-3.99	0.79	-10.96	-19.68	-18.27	1.94	-10.42	3.70	25.53	35.11
Δ in the Specialist's Inventory*	3.56	4.86	-0.06	-0.57	4.83	-0.75	2.34	1.71	27.66	39.36
Previous % Spread	-102.11	-280.64	-18.97	-104.01	-314.38	45.93	-21.89	-175.28	98.94	98.94
Previous Posted Bid Depth*	1.24	3.25	-54.85	-59.20	-46.13	6.57	7.26	6.51	100.00	100.00
Previous Posted Ask Depth*	-43.59	9.52	0.52	-47.56	10.27	1.47	-35.42	10.12	100.00	100.00

Table 8. cont'd

Panel B. Mean Impulse Sensitivites (%)

	9 Choices Available to the Specialist								
Exogoneous Variables	**D-D**	**D-PS**	**D-PL**	**PS-D**	**PS-PS**	**PS-PL**	**PL-D**	**PL-PS**	**PL-PL**
Δ in the Best Limit Bid Price	-5.59	-5.26	-2.82	3.98	1.50	5.83	-0.84	0.71	2.49
Δ in the Best Limit Ask Price	-22.53	4.62	5.23	-1.83	5.02	2.29	-1.41	5.52	3.09
Δ in the Best Limit Bid Size	0.39	0.16	0.22	-0.11	-0.12	-0.16	-0.17	-0.08	-0.13
Δ in the Best Limit Ask Size	-0.33	-0.09	0.39	-0.04	-0.08	0.05	0.18	-0.10	0.01
Δ in the % Best Limit Bid Gap	-9.56	-7.59	-5.55	9.56	3.57	5.74	2.04	0.09	1.70
Δ in the % Best Limit Ask Gap	-11.78	0.02	0.69	0.99	2.29	5.10	-2.18	0.83	4.03
Δ in the LOB Asymmetry	0.64	-0.27	-0.96	0.33	0.04	-0.13	0.32	0.10	-0.08
Cumulative Limit Buy Order Placement	1.34	0.39	0.38	-1.19	-0.43	-0.23	-0.13	-0.07	-0.06
Cumulative Limit Sell Order Placement	1.06	-1.47	0.69	0.21	-0.52	-0.02	0.27	-0.25	0.02
Cumulative Cancelled Limit Buy Orders	-1.10	-0.44	-0.31	1.27	0.14	0.17	0.25	0.01	0.02
Cumulative Cancelled Limit Sell Orders	-2.15	1.82	0.36	-0.43	0.22	-0.01	-0.11	0.26	0.05
Elapsed time between last two LOB revisions	-0.04	-0.07	0.07	0.05	0.05	-0.11	0.04	-0.05	0.06
Volatility	-1.24	0.22	0.89	-0.22	-0.02	0.12	-0.03	0.02	0.25
Buy volume since the last quote revision	0.96	-0.08	-0.30	-0.55	-0.16	-0.18	0.34	-0.01	-0.01
Sell volume since the last quote revision	-1.18	-1.54	0.91	-0.79	-0.36	0.63	1.39	0.22	0.72
Δ in the Specialist's Inventory	-0.44	0.33	0.30	-0.12	-0.01	0.02	-0.12	0.03	0.01
Previous % Spread	3.02	-1.32	-3.61	0.22	0.04	-0.43	1.66	0.38	0.05
Previous Posted Bid Depth	-0.17	0.97	2.19	-4.59	-1.28	-0.99	2.43	0.62	0.82
Previous Posted Ask Depth	-2.41	-7.07	8.22	0.13	-1.55	2.15	0.46	-1.21	1.28

Table 9. OLS Results from Cross-sectional Regression of Specialist Participation

This table reports results from estimation of equation 1. Standard errors are reported in parentheses. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Dependent variable is the sum of average percentage specialist participation at the bid and ask.

Dependent Variable	
Sum of average percentage specialist participation at the bid and ask	
Exogenous Variables	**Coefficients**
Intercept	0.337 ***
	(0.095)
Log Mean Daily Volume	-0.047 ***
	(0.015)
Log Market Capitalization	0.03098 **
	(0.013)
Relative Tick	-19.283 **
	(7.65)
Volatility (Std. Dev. of Transaction Prices)	0.090 *
	(0.043)
Average Percentage Spread	-0.629
	(2.612)
Sample Size	114
R^2	0.17

Table 10. OLS Results from Cross-sectional Regression of Future Returns

This table reports results from estimation of equation 2 for each of the 38 stocks in our sample. For each future return regression (k=5 minutes, 1 hour, or 1 day), mean and standard error of all coefficient estimates across stocks are reported. The last two columns report the number of positive and negative coefficients. A positive (negative) coefficient of percentage specialist participation to the bid (ask) quotes or bid (ask) side interaction variable indicates that the specialist predicts the direction of future return correctly. The last column reports thepercantage of correct predictions for the relevant independent variable.

	k = 5 minutes				
Variables	**Average of Estimated Coefficients**	**Std. Error of Estimated Coefficients**	**Negative**	**Positive**	**% Correct**
Intercept	-0.0568	3.1561	58	81	
Lagged Return	-0.0010	0.0525	75	64	
Specialist participation to the posted Bid	-0.3663	4.7509	86	53	38.13
Spec Part. Bid x Spec. Bid Depth	0.0004	0.0022	40	99	71.22
Specialist participation to the posted Ask	0.2347	5.8364	61	78	43.88
Spec Part. Ask x Spec. Ask Depth	-0.0009	0.0052	114	25	82.01
LOB Asymmetry Close to the Best Limit Prices	-2.61E-05	5.44E-05	109	30	78.42
Overall LOB Asymmetry	-5.19E-06	5.25E-05	63	76	45.32

	k = 1 hour				
Variables	**Average of Estimated Coefficients**	**Std. Error of Estimated Coefficients**	**Negative**	**Positive**	**% Correct**
Intercept	-5.3478	49.5499	62	77	
Lagged Return	-0.0278	0.1317	85	54	
Specialist participation to the posted Bid	-1.8902	21.0177	78	61	43.88
Spec Part. Bid x Spec. Bid Depth	0.0029	0.0119	48	91	65.47
Specialist participation to the posted Ask	-0.7085	23.6373	67	72	48.20
Spec Part. Ask x Spec. Ask Depth	0.0000	0.0121	96	43	69.06
LOB Asymmetry Close to the Best Limit Prices	-6.87E-05	4.73E-04	95	44	68.35
Overall LOB Asymmetry	-1.11E-05	3.72E-04	47	92	33.81

	k = 1 day				
Variables	**Average of Estimated Coefficients**	**Std. Error of Estimated Coefficients**	**Negative**	**Positive**	**% Correct**
Intercept	-141.1554	600.1769	71	68	
Lagged Return	-0.0269	0.3305	80	59	
Specialist participation to the posted Bid	-13.1692	69.0943	81	58	41.73
Spec Part. Bid x Spec. Bid Depth	0.0016	0.0309	64	75	53.96
Specialist participation to the posted Ask	2.3429	84.8441	70	69	50.36
Spec Part. Ask x Spec. Ask Depth	-0.0080	0.0886	82	57	58.99
LOB Asymmetry Close to the Best Limit Prices	-4.73E-04	2.20E-03	106	33	76.26
Overall LOB Asymmetry	1.76E-04	1.59E-03	28	111	20.14

Appendix A

Information about the sample that consists of 143 stocks we employ to compare specialist strategies.

Symbol	Data Period	Symbol	Data Period	Symbol	Data Period	Symbol	Data Period
AIG	x	FMO	xx	MRK	x	SZ	xx
ALS	xx	FNM	x	MU	x	T	x
AOT	xx	FOE	xx	MWC	xx	TGT	x
AP	xx	FTD	xx	MWD	x	TLM PRB	xx
AVB	xx			MXE	xx	TMK	x
AXP	x	GGT PR	xx	NAP	xx	TRP	xx
AXP PRA	xx	GLW	x	NKE	x	TYC	x
BAC	x	GNA	xx	NOK	x	UBT	xx
BBV	xx	GPS	x	NPC	xx	UDS	x
BK	x	GPT	x	NR	xx	UMG PRY	xx
BKE	xx	GRP	xx	NUI	xx	USI	xx
BPL	xx	GX	x	OFG	xx	VIAB	x
BRM	xx	HD	x	OMX	xx	VOD	x
BZL	xx	HI PRT	xx	ONE	x	VTP	xx
C	x	HIF	xx	OUI	xx	WB	x
CB	x	HPT	xx	PBR	xx	WFC	x
CBA	xx	HRC	x	PCG	x	WMK	xx
CHH	xx	HWP	x	PCS	x	WMS	xx
CLP PRA	xx	IBM	x	PFE	x	WMT	x
CM	xx	IMY	xx	PFP	xx	XOM	x
CMS	x	IRT	xx	PNK	xx	XRX	x
CNC	x	JBL	x	PP	xx	ZNH	xx
CPN	x	JPM	x	PST PRA	xx	ZNT	xx
CQB PRA	xx	JPM PRC	xx	PTM	xx	ZQK	xx
CSD PRA	xx	JW B	xx	Q	x	ZTR	xx
CUZ	xx	KGC	xx	RI	xx		
CWF	xx	KM	x	RKY	x		
DIS	x	KWD	xx	ROM PR	xx		
DL	xx	LMGA	x	SBC	x		
DRE	xx	LNC PRG	xx	SBP PRA	xx		
DRE PRA	xx	LNC PRY	xx	SCH	x		
DUC	xx	LTD	x	SGP	x		
EIX	x	MC	xx	SJI	xx		
ELY	x	MCD	x	SJR	xx		
ENE PRT	xx	MER	x	SKO	xx		
EQT	x	MIJ	xx	SLR	x		
F	x	MKT	xx	SQM A	xx		
FCP	xx	MO	x	SSS PRB	xx		
FIG PRA	xx	MOT	x	SUS	xx		

x : 04/02/2001 - 04/06/2001
xx: 04/02/2001 - 06/29/2001

Chapter 2

Participation Strategy of the NYSE Specialists to the Trades

Abstract

Using 2001 NYSE system order data in the decimal pricing environment, we analyze how the specialists react to the changes in market variables while making participation decisions to the trades. We analyze the following options that are available to the specialist before he trades: do not participate; participate at the quoted price; participate and improve the price. We find that the specialist uses information in the limit order book as summarized by the limit order book asymmetry. The specialist increases the probability that he participates to the trade when a market order arrives if he is able to step in front of the heavy side of the LOB. If the relative size of the market order, as described by the ratio of the market order size to the posted depth at the relevant side of the market, is high, the specialist chooses not to participate and let the market order trade with the limit order book. Consistent with the theoretical results in the previous literature, specialists trade more aggressively when the spread is large. We find that specialist trading strategies in stocks from different volume and price categories vary substantially. Finally, we also find significant inventory effects. The specialist trades more aggressively, if the trade with the incoming market order restores his inventory.

1. Introduction

New York Stock Exchange (NYSE) specialists are responsible for making markets for the stocks assigned to them. Their primary obligation is to ensure that there exists a fair and orderly market in their stocks. They should be willing to trade when other traders are unwilling to trade and the bid-ask spread should not be too wide. Also the specialists should intervene to prevent large price jumps, i.e., they should create price continuity. The NYSE uses the average width of the quoted bid/ask spread, the average depth of the quotes, the number of large price jumps, and the average size of price reversals to evaluate specialists' performances. The specialists' also have "negative obligations" that restrict their trading. Specialists cannot trade for their own accounts if there exist public orders at the same price or better. Also they should not trade with limit orders in order not to take the liquidity available to public traders. [35]

In this paper, we investigate the following issues by analyzing the participation decisions of the specialists to trades on the NYSE. First, what affects the participation strategy of a specialist to trades over time in an individual stock? Specifically, does he trade according to his affirmative obligations? Does he use information from the Limit Order Book (LOB) to predict the future returns of the stocks? Does he manage his inventory by using trades as inventory theories suggest? What is his reaction to the possibility of informed trading? Does he increase his participation to the trades to smooth prices when prices are volatile or does he avoid trading to stay away from risks inherent in volatile markets? Second, how do specialists' trading strategies vary across stocks? Specifically, what is the effect of volume on specialists' decisions? Does the specialist

[35] See Harris (2003) p.494 for an extensive description of specialists' roles and how they can act against the interests of the public investors on the NYSE.

trade aggressively or defensively as the price volatility increases across stocks? Is the relative tick size, as defined by the ratio of the minimum tick to stock price, important in trading strategy of the specialists?

The answers to these questions are very important because NYSE specialists make markets for a huge trading volume. On the NYSE, the dollar value of average monthly trading volume that the specialists oversee was $968.18 billion and average specialist volume as percentage of the NYSE total volume was around 20% in 2004.[36] Therefore, the average dollar volume that the specialists traded for their own accounts per month can be approximated as $193.64 billion. Specialists take one side of this huge trading activity and there are potential conflict of interests between the specialists desire to make profits for themselves and their obligation to be fair to all public traders. There has been an important debate going on about the role of the specialists and whether their contributions are valuable in the overall trading activity. Recently, as a result of an investigation by the U.S. Securities and Exchange Commission into floor trading practices, five largest specialist firms at the New York Stock Exchange were required to pay a combined $241.8 million to settle charges of improper trading.[37] More recently, the New York Times reported that the United States attorney's office was investigating individual specialists for executing proprietary orders before customer orders, and getting involved in a trade that should be carried out automatically with no intervention.[38]

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[36] See "Market Activity" in the NYSE fact book that can be found at http://www.nysedata.com/factbook/. Generally, the specialist participation rate mentioned in the literature is the specialist volume as percent of NYSE 2x total volume which was approximately 10% in 2004. If one wants to calculate the total volume that the specialists traded for their own accounts, specialist volume as percent of NYSE total volume is the correct figure to use.

[37] See for example, *Wall Street Journal* (October 16, 2003) "NYSE to Punish Five Specialists In Trading Inquiry".

[38] "A New Inquiry Into Big Board Specialists", *New York Times*, February 7, 2005. This paper does not address the issue of improper trading.

The NYSE claims that investors get the best available price most of the time in the specialist system. But many institutional investors prefer faster executions and believe that the human-based system for auctioning stocks does not allow this.[39] To address these concerns, the NYSE is planning to allow investors to execute more stock orders automatically.[40]

Despite the important role played by the NYSE specialists, one can find little or no analysis of their trading strategy. One reason for this lack of analysis in the previous literature is the lack of the data. To provide a meaningful analysis of specialist behavior, one needs detailed data about orders. Publicly available TAQ database contains information about volume and prices of individual transactions on the NYSE. However, this transaction data provides no information about specialist participation in individual trades. In addition to TAQ, the NYSE provided researchers with TORQ (Trades, Orders, Reports, and Quotes) database that contains transactions, quotes, order processing data, and audit trail data for a sample of 144 stocks for three months: November 1990 through January 1991.[41] This database can be used to partition posted depth into the specialist's contribution and the LOB's contribution (which is necessary for our analysis). Since the specialist IDs are removed from the TORQ database, one should rely on algorithms similar to the one provided in Panchapagesan (2000) to infer the trades with the specialist participation.

Considering the numerous changes in the trading system and procedures that occurred on the NYSE since 1991, TORQ database cannot provide much information

[39] See "Fidelity Urges NYSE to Revamp Trading Operation", *Wall Street Journal*, October 14, 2003.
[40] See"NYSE's Automatic Transition", *Wall Street Journal*, June 22, 2004 and NYSE Newsletter August 2004 issue on http://www.nyse.com.
[41] See Hasbrouck (1992) for a detailed description of TORQ database.

about the recent behavior of quotes and transactions.[42] Because of the public order precedence rule, the specialist has to better the quotes in the LOB if he wants to trade. The trading strategy of the specialists changed considerably after the decimalization in the NYSE, because undercutting the LOB became less costly now. [43]

When a market or marketable order arrives, the specialist faces the decision of choosing between the following strategies: i. Do not participate; ii. Participate at the quoted price; and iii. Participate and improve the price. Using 2001 NYSE system order data in the decimal pricing environment, we analyze how the specialist reacts to the changes in the market variables while choosing one of the three strategies above. To complete this analysis, it is important to determine the position of the specialist in the posted quotes, because this position is a constraint on specialist's strategy. For example, if a market buy order of size 100 arrives and the posted ask depth of 200 is coming from the specialist *only*, the specialist has no option but to trade with this market buy order unless another trading interest appears at the same time that can be matched with this market buy. In our example, if we did not look at the position of the specialist in the posted ask, we would incorrectly think that the specialist took the contra side of this market buy strategically, reacting to changes in market variables, where in fact he did not have any choice other than trading with the market buy. Accordingly, for each trade, we determine the position of the specialist in the posted quotes and determine his feasible strategies that do not contradict his affirmative obligations. Analyzing trading decisions of the specialists allows us to see if their trades are consistent with their market making

[42] The most important change is the switch to decimal pricing. For a list of other rule changes since 1997, visit http://apps.nyse.com/commdata/PubInfoMemos.nsf/AllPubRuleChanges?openview&count=500 .
[43] See Coughenour and Harris (2003) and references therein.

obligations as described above, or if they take away liquidity from the market for their own profits.

This work is related to a number of papers in the previous literature. Madhavan and Sofianos (1998) analyze specialist participation in the total transaction volume. Harris and Panchapagesan (2005) show that LOB is informative about future prices and specialists use this information. [44] In this paper, we extend and complement their analysis in a number of ways. First, as described above, we take the position of the specialist in the posted quotes as given. So we are able to answer the question that "given his position in the posted quotes, i.e., given his participation strategy to the posted quotes, how does the specialist participate to the trades?". Second, we analyze the trading strategies of the specialists in the decimal pricing environment. The decimalization had many effects on the market variables including the profits of the specialists.[45] Therefore, our study also contributes to the previous literature by showing how the strategies of the specialists changed after the decimalization.

Our results from analyzing individual stocks over time indicate that the primary variables that the specialist looks at are the "Excess Spread", defined as spread minus minimum tick, and the "Relative Order Size", defined as the ratio of the market order size to the posted depth at the relevant side of the market. As the excess spread increases, more room is available for the specialist to undercut the LOB, and he trades more aggressively. This aggressiveness can also be the result of the specialists market making obligations. Since an increase in the spread is an indication of a weak market, the specialist might simply be trading because he has an obligation to trade when no one else

[44] See Ready (1999) also.
[45] See Coughenour and Harris (2003) and references therein.

is willing to trade. When the size of the market order relative to the posted bid size increases, the specialist increases the probability that he lets the market order trade with the LOB to protect himself from the possibility of informed trading.

The specialist increases the probability that he participates to the trade when a market order arrives if he is able to step in front of the heavy side of the LOB. In addition, the specialist uses information from the cumulative order imbalance since the last trade to update his beliefs about the true value of the stock. If the order imbalance, defined as cumulative buy volume minus sell volume during the last 15 minutes or 15 trades increases (decreases), the specialist increases the probability that he undercuts the LOB when a market sell (buy) arrives.

We also find significant inventory effects. The specialist trades more aggressively, if the trade with the incoming market order restores his inventory.

The effects of other variables seem to be secondary. There is some evidence that when the size of the arriving market order is medium, the specialist decreases the probability of participating in the trade, which supports the finding of Barclay and Warner (1993) that informed traders prefer medium sized orders.

The rest of the paper is organized as follows. Section 1 describes the determinants of the specialist trading strategy predicted by the previous literature and states the hypotheses. Section 2 describes the data. Empirical methodology is discussed in section 3. Section 4 presents the results from our analysis and Section 5 concludes.

2. Hypotheses

2.1. The determinants of specialist participation to trades over time

As first analyzed by Stoll (1978), Ho and Stoll (1981, 1983), the risk of carrying inventory induces a positive bid-ask spread. However, many previous studies (e.g. Madhavan and Smidt (1993), Hasbrouck and Sofianos (1993), Kavajecz and Odders-White (2001)) find weak inventory effects. Madhavan and Sofianos (1998) provide evidence that specialists manage their inventories through the timing and direction of their trades rather than adjusting bid and ask quotes. Therefore, we expect a risk averse specialist to increase (decrease) the probability of taking the contra side of a market buy (sell) order when he has a long inventory position and, inversely, to decrease (increase) the probability of taking the contra side of a market buy (sell) order when he has a short inventory position.

Seppi (1997) models the competition between limit order traders and a strategic specialist. He shows that when the bid-ask spread is greater than the minimum tick, the specialist undercuts the LOB for small trades. As the spread increases, there will be more price points that the specialist can use to undercut the LOB and make profits. Also, a wide spread might cause large jumps in the prices. Therefore, a large spread may induce the specialist to increase his participation because he has the market making obligation to maintain price continuity. Accordingly, we expect that the specialist increases the probability that he participates in a trade when the bid-ask spread is large.

Easley and O'Hara (1992) shows that time between trades can be correlated with the factors related to the value of the asset. In their model, the frequency of trades is positively correlated with the occurrence of an information event. If no trade occurs in

some time interval, the market maker raises his probability that no information event has occurred. Accordingly, he moves his bid and ask quotes closer to the true value of the stock, which is between bid and ask prices, because the probability of trading with an informed trader is low. This implies that the spread will be smaller as the time between trades increases.[46] In the context of our model, we expect that as no-activity time increases, the specialist increases the probability that he participates to the next trade.

The state of the LOB is an important factor considered by the specialist while determining his strategy to participate in the trades. During our sample period, the specialists were required to share the general information about the LOB with the floor brokers when asked.[47] However, this information was not available to most traders in the market, so the specialist had considerable advantage in having access to the LOB. In Seppi (1997) model, limit order traders are the primary source of competition that the specialist faces. Harris and Panchapagesan (2005) find that specialist uses information from the LOB in ways that favor him. They argue, for example, that an asymmetry in the LOB predicts the likely direction of future price changes.

Specialists may also use quote-matching strategies.[48] As described in Harris (2003), quote matching is a front-running strategy in which quote matchers try to trade in front of large patient traders. For example, when a quote matcher trades (buys) in front of a large buy limit order, and prices move against him, he limits his losses by trading with the standing buy limit order. When a specialist buys in a similar situation, and the prices

[46] For a similar result, see Easley, Kiefer and O'Hara (1997). For evidence of transaction clustering, see Admati and Pfleiderer (1989) and Engle and Russell (1998).

[47] Recently, the NYSE started selling aggregate order book volume at each price point through its new system called the NYSE OpenBook™. The information in this system is updated every 5 seconds. This reduces but does not eliminate the informational advantage of the specialists because they still have exclusive access to *individual* orders. For more information, visit http://www.nysedata.com/openbook/. For the effects of the NYSE OpenBook™, see Boehmer, Saar and Yu (2003).

[48] See Harris (2003), p.248 and p.502.

move against him, he should not trade with the limit buy order (a negative obligation) but at least he does not need to be on the contra side of upcoming market sells until the liquidity on the buy side of the LOB is exhausted.

If the specialist exploits the information in the LOB, we would expect that when the LOB is heavy on the buy (sell) side, he increases the probability that he participates to the trade when a market sell (buy) arrives. There are two reasons for this. One of them is quote matching as described above. The second one is having information about the direction of future price changes. On the other hand, if the specialist trades according to his affirmative obligations, he would increase the probability that he participates to the trade when a market buy (sell) arrives at times when the LOB is heavy on the buy (sell) side to maintain price continuity. The effect of LOB asymmetry on the specialist's participation strategy to the trades is therefore an empirically open question.

In Kyle (1985) model, the market maker revises his expectations about the value of the stock upwards (downwards) and increases (decreases) the stock price as result of buy (sell) orders which possibly includes orders coming from informed traders. Although there are no bid and ask prices in the Kyle model, the idea is that the market maker updates his belief of what the stock is worth and adjusts the price so as to minimize his loss to informed traders. Obviously, this updated belief about the value of the stock will be crucial for the specialist when he has to decide whether to take the contra side of a market order. We expect that, as the buy (sell) transaction volume since the last trade increases, the specialist increases (decreases) the probability that he participates when a market sell order arrives, and decreases (increases) the probability that he participates when a market buy order arrives.

Barclay and Warner (1993) shows that most of the cumulative stock-price change is due to medium-size trades providing evidence consistent with the hypothesis that informed trades are concentrated in the medium-size category. Following Madhavan and Sofianos (1998), we define a trade as medium if it is between 50^{th} and 99^{th} percentile in size. We expect that, the specialist decreases the probability of his participation if the size of the market order is medium.

Dupont (2000) shows that the market maker reduces depth when the volatility of the asset value is high. Intuitively, high volatility increases the risks associated with carrying inventory which will result in less specialist contribution to depth. On the other hand, Madhavan and Sofianos (1998) state that "Price continuity rules require specialists to trade to stabilize prices, suggesting that participation will be higher in stocks whose intraday return volatility is large." In a cross sectional analysis of specialist participation, they find a positive relationship between their volatility variable and the specialist participation rate. Bondarenko and Sung (2003) theoretically show that when the price volatility is high, the optimal strategy of the specialist is to increase his participation even when he is not constrained by the rules imposed by the exchange. The effect of volatility on the specialist's quoting decision is therefore an empirically open question.

Peterson and Sirri (2002) find that "marketable limit orders are used proportionally more often: i) for larger orders, ii) by non-individual investors, iii) when the order size exceeds quoted depth, iv) when quote imbalances exist, v) when the depth is relatively low, and vi) when spreads are narrow." Therefore it is more difficult and less profitable to execute a marketable limit order for the specialist. We expect that, if the

arriving order is a marketable limit order, the specialist decreases the probability that he chooses strategy 3, i.e., strategy of undercutting the LOB.

2.2. Cross-sectional determinants of specialist participation to trades

Previous theoretical literature shows that specialists' services are more valuable for illiquid stocks. We expect that specialist percentage participation to trades should decline as the liquidity of the assigned stock increases. Trading volume and market capitalization can be used as proxies for liquidity. So there should be an inverse relationship between specialist's participation and these proxies.

As discussed in detail in the previous section, when volatility is high, the specialist might reduce depth because of the risks associated with carrying inventory, or he might increase depth to stabilize the prices. Madhavan and Sofianos (1998) find a positive relationship between the volatility as measured by the standard deviation of the midquote to midquote transaction returns, and the specialist participation rate in a cross sectional analysis of specialist participation. The effect of volatility on the specialist's participation decision to quotes is an empirically open question.

Seppi (1997) analyzes a model in which specialists face direct competition from public limit orders that have precedence under the NYSE rules. He shows that specialist's profits are maximized as the tick size goes to zero. The reason is that as the tick size approaches to zero, it becomes less costly for the specialist to undercut the LOB. The tick size on the NYSE switched from eights to sixteenths on June 24, 1997 and to pennies for a number of stocks on August 28, 2000. Finally, on January 29, 2001, all NYSE stocks

started being traded in pennies.[49] This decrease effectively relaxed the public order precedence rule and increased the set of prices over which the specialist can choose to undercut the limit orders. As predicted by the Seppi model, Coughenour and Harris (2003) find empirically that participation rates and high frequency trading profits increased for specialists making markets for low price stocks as a result of decimalization. In the context of our model, it is more costly for the specialist to undercut the LOB for low price stocks which implies that the specialist participation to the trades will be inversely related to the "Relative Tick" defined as the ratio of the minimum tick ($0.01) to the stock price.

3. Data

Our data is from the NYSE System Order Database (SOD). Because of the volume of the data, it is necessary to select a sample of NYSE-listed securities. The original sample is selected as follows: Initially, 50 most actively traded NYSE stocks during the 20 trading days prior to January 29, 2001 are chosen. Also 25 stocks from each of four Volume-Price groups are randomly selected. To pick the 100-stock random sample, NYSE-listed securities are ranked on share trading volume and, separately, on average NYSE trade price during the 20 trading days prior to January 29, 2001. Each security is placed into one of four categories after comparing its share price to the median NYSE share price and its trading volume to the median NYSE volume. These groups (of unequal numbers of stocks) are a high-volume:high-price group, a high-volume:low-price group, a low-volume:high-price group, and, a low-volume:low-price group. Within each

[49] See the "trading" column in NYSE timeline at http://www.nyse.com/about/timeline/TimeLine.html.

group, securities are arranged alphabetically (by symbol) and every Nth security is chosen, where N is chosen to select 25 securities from that group. Because two of the 50 stocks with the highest trading volume also are randomly chosen as part of the high volume groups, the final sample has 148 securities.

NYSE's System Order Database (SOD) gives detailed information on the entry and processing of orders. Order data include security, order type, a buy-sell indicator, order size, order date and time, limit price (if the order is a limit order), and the identity of the member firm submitting the order. Execution data include the trade's date and time, the execution price, the number of shares executing, and cancellation information. Orders, executions and cancellations are time-stamped to the second.

Because of the size of the dataset, we estimated the LOBs for active stocks for one week (April 2nd ,2001 – April 6th, 2001) only. For the rest of the stocks we estimate the LOBs for three months(April 2nd, 2001 – June 29th, 2001). See the appendix for the symbols and data period for each stock used in the analysis.

To determine the available strategies to the specialist when a market order arrives, we have to determine his position in the posted quotes. For example, as discussed in detail in Section 3.2.1 below, if the specialist represents all depth in the posted bid quote which is equal to 1000 shares, and if a market sell order of size less than 1000 arrives, the specialist has no choice but to take the other side of this trade (assuming that there does not exist a simultaneously arriving public order that could be matched with this market sell). [50] Since the posted quotes reflect trading interests of the limit order traders, floor brokers and the specialist, we need to estimate the LOB to separate the portion of the posted depth coming from the LOB. The LOBs are estimated by using the method

[50] Our sample also contains marketable limit orders.

described in Kavajecz (1999). First, the limit order book at the beginning of the sample period is estimated by searching for all execution and cancellation records that refer to orders placed before the sample period. Second, initial and each limit order book after that is updated sequentially depending on the placed orders, executions and cancellations. The result is the estimate of the LOBs at each point in time. After the LOBs are estimated, if the posted bid (ask) price is the same as the best limit bid (ask) price, then the LOB bid (ask) depth is subtracted from the posted bid (ask) depth. The *residual* depth comes from the specialist's trading interest and the orders left by the floor brokers with the specialist for the specialist to execute (passive floor broker participation). We call this residual as the "specialist's participation to the posted quotes" and use it to determine the position of the specialist in the posted quotes.[51] Sofianos and Werner (2000) estimate by using data from January 1997 to February 1997 that passive floor broker participation rate is 10.6% of buy plus sell volume of all purchases and sales. The remaining trade volume belongs to the specialist (10.8%), system orders (44.9%), and orders actively represented by the floor brokers (33.7%).

To calculate the transaction volume used in our analysis, we use Lee and Ready (1991) method to classify transactions in the TAQ database of the NYSE as buyer- or seller-initiated.

[51] Our dataset does not allow us to split out the passive floor broker participation.

4. Empirical Methodology

4.1. Stock by Stock Analysis (Specialist participation over time)

When a market or marketable order arrives, the specialist faces the decision of choosing between the following strategies:

1. Do not participate,

2. Participate at the quoted price,

3. Participate and improve the price.[52]

Not all of above strategies are available to the specialist for all incoming market orders. Availability of the above strategies depends on the position of the specialist in the posted quotes. As an example consider the following scenario: The posted bid size is 1000 shares all of which comes from the LOB. Then, a market order to sell 500 shares arrives. In this case, only the choices 1 and 3 are available to the specialist. The specialist cannot participate at the quoted price because of the public order precedence rule.

Table 1 reports the percentage of each quote case for different volume and price categories of stocks. We observe from the table that specialists quote more aggressively for low-volume stocks. Average percentage of bid (ask) quotes in which specialists undercut the LOB for low-volume stocks is 31.78 % (29.85 %) and the respective numbers for high-volume stocks is 15.54 % (18.95 %). One reason might be that low-volume stocks have thin LOBs and they need more specialist participation. Another observation is that the specialists quote more aggressively for high-price stocks. A

[52] In their analysis of specialist trading decisions, Harris and Panchapagesan (2003) add one more case which is to "stop the order". The percentage of stopped orders in our sample is around 0.01%. Accordingly, we exclude this choice from our analysis.

possible explanation consistent with the discussion in Section 1.2 is that as the relative tick size approaches zero, it becomes less costly for the specialist to undercut the LOB.

We determine the strategies for different cases as follows. Let's partition the posted bid depth into two parts that come from the specialist and the LOB. [53] So posted bid depth equals $S_B + L_B$, where S_B comes from the specialist, and L_B comes from the LOB. Let M_S denote the size of the incoming market sell. There exist three possible quote conditions according to the values that S_B and L_B take and for each quote condition there are two possible cases depending on the size of the incoming market sell order, M_S.[54] Therefore we have the following 6 cases for bid quotes (mirror image holds for the ask quotes).

Case 1. $S_B = 0; L_B > 0; M_S > L_B;$ LOB provides all depth; Market sell size > bid depth.

Case 2. $S_B = 0; L_B > 0; M_S \leq L_B;$ LOB provides all depth; Market sell size ≤ bid depth.

Case 3. $S_B > 0; L_B > 0; M_S > L_B;$ Mixed Case ; Market sell size > bid depth.

Case 4. $S_B > 0; L_B > 0; M_S \leq L_B;$ Mixed Case; Market sell size ≤ bid depth.

Case 5. $S_B > 0; L_B = 0; M_S > L_B;$ Specialist provides all depth; Market sell size > bid depth.

Case 6. $S_B > 0; L_B = 0; M_S \leq L_B;$ Specialist provides all depth; Market sell size ≤ bid depth.

Below, we discuss the strategies available to the specialist for each of the 6 cases.

Case 1: $S_B = 0; L_B > 0; M_S > L_B$

[53] We only discuss the cases for the bid quotes, as the cases for the ask quotes are the mirror image.
[54] Koksal (2005a) analyzes specialist's decision of how much depth to add to the posted quotes in addition to the LOB.

If the size of the incoming market order is greater than the posted bid depth, i.e., if $M_S > L_B$, then all three strategies are available to the specialist. Specifically, he may let the market order trade with the LOB; he may participate at the quoted price since the size of the market order is greater than the posted bid depth; or he may participate and improve the price and trade with the market order alone. This quote case provides the specialist with the highest degree of freedom, because since the size of the market order is greater than the corresponding depth coming from the LOB, the specialist can implement his strategy by choosing strategy 2 or strategy 3.

In this paper, we only analyze the initial decision of the specialist when the market order arrives. For example, the specialist may choose to fill *part* of the market order by participating and improving the price and he may let the remaining part filled by the LOB. We do not distinguish between filling the orders partially or completely.

Case 2: $S_B = 0;\ L_B > 0;\ M_S \leq L_B$

If the size of the incoming market order is less than or equal to the posted bid depth, i.e., if $M_S \leq L_B$, then the specialist has the option to do nothing and let the market order trade with the LOB, or he can participate and improve the price. Hence, only the first and third strategies are available.

Case 3: $S_B > 0;\ L_B > 0;\ M_S > L_B$

In this case, the specialist cannot choose strategy 1, i.e., the choice of "not participating". He has to choose either strategy 2 and participate to the trade at the quoted price, or he can undercut the LOB and fill this order completely for his own account. Therefore, the available strategy set is {Strategy 2, Strategy 3}.

Case 4: $S_B > 0;\ L_B > 0;\ M_S \leq L_B$

In this case, the specialist cannot participate at the quoted price because of the public order precedence rule; hence second strategy is not available to the specialist. The available strategy set is {Strategy 1, Strategy 3}.

Case 5: $S_B > 0;\ L_B = 0;\ M_S > S_B$,

In this case the specialist has no choice but to trade with the market order. Therefore, we don't analyze this case.

Case 6: $S_B > 0;\ L_B = 0;\ M_S \leq S_B$,

Similar to Case 5 above, the specialist does not have any strategies to choose.

Table 2 lists all possible quote cases, and the available strategies of the specialist. In this table, S_B and S_A also include some orders left by the floor brokers with the specialist.

Given that a particular quote condition is $S_B = 0;\ L_B > 0$ or $S_B > 0;\ L_B > 0$, we use a multinominal logit framework to analyze Case 1, where all three strategies are available, and a logit framework to analyze the Cases 2, 3, and 4, where only two strategies are available.

4.2. Explanatory variables for stock by stock analysis

We use a multinominal logit model for our time series analysis of the specialist participation to the trades. This model will be discussed in more detail in Section 3.3 below. To test the hypotheses formulated in the first section we use the following variables for the time series analysis.

Excess Spread is the current quote spread minus the minimum tick in cents;

Relative Order Size is the log ratio of the market buy (sell) order size to the posted ask (bid) depth;

LOB Asymmetry is the total size of the sell limit orders minus the total size of the buy limit orders in the LOB multiplied by –1 if the incoming market order is a sell order;[55]

Near LOB Asymmetry is the total sell limit orders minus total buy limit orders within 20 cents of the best limit prices multiplied by –1 if the incoming market order is a sell order;

Signed Cumulative Order Imbalance is the total buy volume minus sell volume in all exchanges during the last 15 minutes or 15 trades whichever is shorter multiplied by -1 if the incoming market order is a buy order;[56]

Specialist's Signed Inventory cumulative inventory of the specialist preceding the trade multiplied by -1 if the incoming market order is a sell order;[57]

Medium Trade Dummy takes the value of 1 if the trade size is between 50^{th} and 99^{th} percentile and 0 otherwise;

Order Type Dummy takes the value of 1 for the marketable limit orders and 0 otherwise.

Volatility is the standard deviation of the transaction prices during the last ten minutes before the current quote;

Trade idle time is the normalized time in seconds since the arrival of the last market order.

4.3. Cross Sectional Analysis

We estimate the following cross-sectional regression model to analyze how the participation of the specialists varies across stocks:

$$SpecPart_i = \beta_0 + \beta_1 LogMeanDailyVol_i + \beta_2 RelTick_i + \beta_3 LogMarketCap_i + \beta_4 Volatility_i + \beta_5 AvePercentageSpread_i + \varepsilon_i \quad (1)$$

[55] If the specialist use information from the LOB as Harris and Panchapagesan (2005) found, they will trade more aggressively when they can step in front of the heavy side of the book

[56] We expect that the specialist will take the contra side of a market sell (buy) order more aggressively if the cumulative order imbalance preceding the trade is positive (negative), i.e., he updates his belief about the security value upwards (downwards) if the buy (sell) volume preceding the trade is greater than the sell (buy) volume. To calculate the transaction volume used in our analysis, we use Lee and Ready (1991) method to classify transactions in the TAQ database of the NYSE as buyer- or seller-initiated.

[57] We assume that the inventory of the specialist is equal to zero at the beginning of the period and ignore overnight changes in the inventory. Harris and Panchapagesan (2005) use this variable too. If the specialists manage inventory, they will trade more aggressively, i.e., increase the probability that they choose strategy 2 or 3, if trading would restore their invento ries.

where, for stock i, $SpecPart_i$ is the percentage of the trades that the specialist participated (at the quote or by improving the price), $LogMeanDailyVol_i$ is the log of average daily volume, $RelTick_i$ is the minimum tick size (=$0.01) divided by the average stock price over the sample period, $LogMarketCap_i$ is the log of shares outstanding times average stock price, $Volatility_i$ is the average of the volatility variable from the time series analysis, $AvePercentageSpread_i$ is the average percentage quoted spread over the sample period and ε_i is the error term.

5. Results

5.1. Stock by Stock analysis

As discussed in Ellul, Holden, Jain and Jennings (2004), the exogenous variables affect the probability of choosing base case strategy, but because of the multinominal logit estimation, this effect can't be determined directly from the coefficients. In addition, occasionally, the signs of the coefficients of the non-base case variables can be different from the signs of their impact on the choices. To solve this problem, following Ellul, Holden, Jain and Jennings (2004), we calculate what they refer to as impulse sensitivities. "Impulse sensitivity" is defined as the change in the probability of an event caused by a one standard deviation increase in an explanatory variable. The benchmark probability of each event is calculated by using the estimated logistic function evaluated at the mean of each of the explanatory variables. The significance of an impulse sensitivity is calculated by the method described in Ellul, Holden, Jain and Jennings (2004).

In this paper, we don't distinguish between the market sells and market buys. Hence all the discussion below applies to both market buys and sells, since the 6 different cases are mirror images of each other for market buys and sells.

Tables 3 through 6 report the results for each of the four quote cases. Panel B of these tables report the impulse sensitivity of the exogenous variables. We will discuss and interpret the mean impulse sensitivities. In all tables, the percentages of significant impulse sensitivities at the 5% level of significance range from 83.6% to 100%.

Case 1. $S_B = 0; L_B > 0; M_S > L_B$ or $S_A = 0; L_A > 0; M_B > L_A$

The mean coefficient estimates from the multinominal analysis are reported in Table 3, Panel A along with overall significance of variables at the 5% and 10% levels. Table 3, Panel B reports the mean impulse sensitivities along with the percentage of impulse sensitivities that are significant at the 5% level for each stock.

In this quote case, if the specialist wants to participate in a trade, he does not need to improve the price, because the size of the market order is large enough. The specialist will improve the price if the remaining size of the market order is not sufficient for the size he wants to trade.

Specialists can use the (possible) information in the buy (sell) transaction volume in two ways. For example, when there is a large buy (sell) transaction volume, this may indicate that the stock price will increase (decrease). Accordingly, first, the specialists can protect themselves by not participating in a trade when a large market buy (sell) order arrives. Second, they can be more aggressive in participating a trade when a market sell (buy) order arrives. The impulse sensitivities for Strategies 1, 2 and 3 are -2.62 %, 0.83 %

and 1.83%, respectively, when the “Cumulative Order Imbalance” increases by one standard deviation. As a result of one standard deviation increase in the “Cumulative Order Imbalance”, the specialist increases the probability that he chooses strategy 3 (participate and improve price) by 1.83 %, increases the probability of strategy 2 by 0.83 percent and decreases the probability that he chooses the first strategy by 2.62 %. Therefore, the specialist acts more aggressively to buy (sell) the stock, when he infers from “Cumulative Order Imbalance” that the stock price will increase (decrease). Hence, consistent with the Kyle (1985) model, he updates his belief of what the stock is worth and adjusts the price so as to minimize his loss to informed traders.

The effect of a one standard deviation in “Excess Spread” is to increase the probability of choosing strategy 3 by 5.54% on average. Probability of choosing other strategies decreases. Consistent with prediction of Seppi (1997), when excess spread increases, the specialist has more room to undercut the LOB, and he acts aggressively when a market order arrives. As discussed before, this result is also consistent with market making obligations of the specialists that they should be ready to trade when nobody else is willing to do so.

In their analysis of specialist strategies, Harris and Panchapagesan (2005) show that the LOB is informative about future price changes and the specialist uses this information. One of the variables that they use as measure of informativeness of the LOB is the overall LOB asymmetry. If the specialist uses information from the LOB, he would try to step in front of the heavy side of the LOB, i.e. he would be more aggressive and increase the probability that he chooses strategy 3. A one standard deviation disturbance to the “LOB Asymmetry” variable causes the specialist to increase his probability of

choosing strategy 3 (stepping in front of the heavy side of the LOB) on average by 0.24%. Hence, the specialist uses the information in the LOB to predict future price changes but this effect seems small.

When the "Near LOB Asymmetry" increases by one standard deviation, the specialist interestingly decreases the probability of the most aggressive strategy by 0.05%. This is in contrast to the results for the overall LOB asymmetry. It seems that the specialists use information from the LOB by using the overall asymmetry, however, they are constrained by their market making obligations and are not always able to step in front of the heavy side of the LOB.[58]

Our results provide some evidence along the lines of the findings of Barclay and Warner (1993) that informed trades are concentrated in the medium-size category. When the size of the market order is medium, the specialist decreases the probability of participating and increases the probability of choosing the most defensive strategy by 1.23%

The impulse sensitivity of strategy 3 for "Order Type Dummy" is -0.38%. The specialist decreases the probability of aggressively participating which is consistent with the implications of Peterson and Sirri (2002) analysis that it is more difficult and less profitable to execute marketable limit orders.

"Relative Order Size" is one of the most important variables for the specialist while deciding whether to participate to a trade. When the size of the arriving market sell (buy) order relative to the posted bid (ask) depth increases by one standard deviation, the specialist decreases his probability of participating to a trade (i.e., choosing strategies 2

[58] Koksal (2005a) shows that the asymmetry in the LOB close to the best limit prices is more informative in predicting the short term price changes.

or 3) by 6.32%. Hence, the specialist is less willing to participate to a relatively large order, possibly coming from an informed trader.

The total impulse sensitivity of choosing strategies 2 and 3 associated with the specialist's inventory is 2.74 %. Hence, the specialist becomes more aggressive in participating to a trade, if the trade would restore his inventory. This supports the results in Madhavan and Sofianos (1998) that specialists selectively participate to trades to manage the inventory.[59]

As the time since the last trade increases, the specialist increases the probability of not participating by 6.27%. The reason might be that, as the idle time increases, the specialist does not have the necessary trading volume as a tool to revise his expectations about the true security value. Accordingly, he decreases probability of his participation to lower the risk of participating to a trade that might be coming from an informed trader.

Finally, as stock price volatility increases, the specialist decreases the probability of becoming more aggressive because the risks of carrying inventory is higher when the volatility of the stock increases.

Case 2. $S_B = 0;\ L_B > 0;\ M_S \leq L_B$ or $S_A = 0;\ L_A > 0;\ M_B \leq L_A$

In this case, the strategy of participating at the quoted price is not available because of the public order precedence rule. Therefore, the specialist must improve the price if he wants to trade. One implication is that, when the specialist wants to restore his inventory for example, he has to be more aggressive. The mean coefficient estimates and impulse sensitivities from the logit analysis are reported in Table 4 along with overall significance of variables at the 5% and 10% levels.

[59] Koksal (2005a) provides some evidence that the specialists also use posted quotes to manage their inventories.

Similar to the previous case, the specialist revises his belief about the stock value by using the “Cumulative Order Imbalance”. The impulse sensitivity of strategy 3 associated with cumulative order imbalance is 2.67%. Therefore, if the buy (sell) volume relative to the sell (buy) volume has been higher, the specialist increases the probability of participating to a trade when a market sell (buy) order arrives, to minimize his losses and make profits.

The “Excess Spread” has the most significant impact on specialist’s choice of undercutting the LOB. The impulse sensitivity of Strategy 3 associated with excess spread is 10.85%. This number is almost twice high as that of the same impulse sensitivity in the previous quote case. Since the size of a, say, market sell order is less than the corresponding bid size in the posted quotes coming from the LOB, when the specialist trades with this market sell, and the prices move against him, he does not need to be on the contra side of upcoming market sells until the liquidity on the buy side of the LOB is exhausted. This is a type of quote-matching strategy discussed in Section1. On the other hand, the reason why the specialists are more aggressive when the spread is large might be the price smoothing obligation of the specialists. They may be improving the price to smooth the prices which otherwise would be more volatile because of the large spread.

The effect of an increase in both the total asymmetry and the asymmetry close to best limit prices in the LOB is an increase in the probability of specialist being more aggressive. Since the LOB asymmetry may be informative for the future price movements as shown by Koksal (2004), and Harris and Panchapagesan (2003), the

specialist increases the probability of being more aggressive if he can step in front of the heavy side of the LOB.

Similar to the previous case, the specialist is less likely to take the contra side of a marketable limit order because since the price is fixed it might be less profitable to trade with this order.

The impulse sensitivity of strategy 3 associated with specialist's inventory is 2.78% indicating that the specialist increases the probability of participating to a trade that will restore his inventory. Interestingly, this change in probability of choosing strategy3 is almost equal to the combined impulse sensitivity of the strategies 2 and 3 (which is 2.74%) associated with the specialist's inventory in quote case 1a. In the previous quote case, since the size of the incoming market order is large enough, the specialist can distribute his probability of participating to this trade to strategies 2 and 3.

The impulse sensitivity of the strategy 3 associated with "Relative Order Size" is negative, i.e., as the relative size of the market order increases the specialist decreases the probability of being aggressive. In the previous quote case, the size of the market order is greater than the posted depth coming from the LOB. Therefore, the size of the market order is relatively larger than the market order in this quote case. Accordingly, the specialist is more aggressive in *not* participating to a trade with the arriving market order in quote case 1 when compared to quote case2.

Case 3: $S_B > 0; L_B > 0; M_S > L_B$ or $S_A > 0; L_A > 0; M_B > L_A$

Table 5 reports the results for quote case 5. This case is similar to case 1 except, the specialist has some depth in the posted quotes now. The specialist's positive depth in the

posted bid (ask) quotes indicates that he is trying to increase (decrease) his holdings of the stocks. Accordingly, we can expect that, when compared to quote case 1, the specialist will be more aggressive, i.e., undercut the LOB, while participating to trades with upcoming market orders. This conjecture is indeed correct. For example, the impulse sensitivity of strategy 3 associated with "Cumulative Order Imbalance" for quote case 3 is 5.45%, which is more than twice as much as the combined impulse sensitivity for the same variable in quote case 1. Similar finding is true for the impulse sensitivity of strategy 3 for the "Excess Spread". The impulse sensitivity of strategy 3 associated with the excess spread in quote case 3 is 21.73%, whereas the same number for quote case 1 is only 5.54%.

As the relative market order size increases by one standard deviation, the probability of choosing strategy 2 (base case) increases by 9.31%. This increase is similar to the previous quote cases, where the specialist increases the probability of not participating as a result of an increase in relative order size. In quote case 3, however, strategy 1 is not an available strategy; hence the specialist increases the probability of the most defensive strategy that he can choose, i.e., strategy 2.

The impulse sensitivities associated with the asymmetry in the LOB is consistent with the previous quote cases. The results suggest that the specialist has some tendency to increase the probability that he participates to a trade, if he can trade in front of the heavy side of the LOB.

The inventory effect is more apparent in this quote case. The impulse sensitivity of strategy 3 related to specialist's inventory is 4.14%. As discussed above, in this quote case, the positive depth coming from the specialist in the posted quotes might be an

indication that the specialist wants to trade. If this depth is related to inventory concerns, we would expect to see that the specialist would be more aggressive in taking the other side of the incoming market order, which is the case here.

Case 4: $S_B > 0;\ L_B > 0;\ M_S \leq L_B$ or $S_A > 0;\ L_A > 0;\ M_B \leq L_A$

Case 4 is very similar to Case 2, in that the strategies available to the specialist are same. Since the size of the arriving market order is less then the depth coming from the LOB, the positive depth that the specialist adds is not very relevant. If he would like to trade, he has to undercut the LOB. There is one difference, however, similar to the difference between quote cases 1 and 3. The positive specialist depth in the quotes indicates that the specialist wants or needs to trade. To increase the probability that he trades, he adds some depth in the relevant side of the posted depth. Accordingly, we expect that the specialist will be more aggressive in participating to the trades in quote case 4, when compared to the quote case 2. The results reported in Table 6 are similar, however, suggesting that these two quote cases are similar to each other.

5.1.1. Trading Volume Effects

There is considerable heterogeneity across stocks as reflected by distribution of estimated coefficients (not reported). Previous literature (e.g. Easley and et al. (1996)) finds that the specialists handle frequently traded stocks and infrequently traded stocks differently. The services of the specialists are mostly needed in thinly traded stocks. In their analysis of posted quote changes, Kavajecz and Odders-White (2001) find that there exist significant differences between high- and low-volume stocks.

To investigate the effect of volume on the strategy of the specialist, we divide the stocks in our sample into two volume categories based on average daily volume. If the average daily volume of a stock is greater than the median, it is considered a high-volume stock; otherwise it is a low-volume stock. The results are presented in Table 7. We report and discuss the impulse sensitivities only.

The impulse sensitivity of the strategy 3 associated to the "Cumulative Order Imbalance" is higher for low volume stocks for all quote cases except for quote case 3. The effect of this variable is higher for low volume stocks, possibly because order imbalance carries more information for illiquid stocks.

The effect of "Excess Spread" is higher for high volume stocks for quote cases 1 and 3, where the size of the market order is greater than the LOB depth in the posted quotes, and higher for low volume stocks for quote cases 2 and 4, where the size of the market order is less than the LOB depth in the posted quotes. This result has two implications. First, the specialist has more information than anyone about an illiquid stock that he oversees, because infrequently traded stocks are not closely followed by investors. In addition, the depth coming from the LOB for illiquid stocks is generally low, resulting in higher frequency of undercutting the LOB by the specialists consistent with their market making obligations to maintain price continuity.

In all four quote cases, the impulse sensitivity of undercutting the LOB associated with the specialist's inventory is higher for low volume stocks. Specialists increase the probability of undercutting the LOB more for low volume stocks if the trade would restore their inventories because inventory management is more difficult for illiquid

stocks. Therefore, whenever they get the chance, they aggressively try to restore their inventory.

5.1.2. Trading Price Effects

Trading price of a stock can be important for the specialists because for the same number of shares, they have to use more capital for high-price stocks. Also, relative tick size, as defined by the ratio of the tick size to stock price, is smaller for the high-price stocks making the public order precedence rule less binding. In their analysis of specialist profits and the tick size, Coughenour and Harris (2003) find that after the decimalization, participation rates and high frequency trading profits increased for specialists handling low-price stocks.

To see if the strategies of the specialists depend on the price of the stocks, we divide the stocks into two price categories. If the mean price of a stock is greater than the median, it is in the high-price category; otherwise it is in the low-price category. Table 8 reports the mean impulse sensitivities according to the price categories.

The effect of inventory on choosing strategy 3 is higher for low-price stocks. This implies that the specialists might be concerned more about the dollar value of their inventories. Since they have to trade more for low-price stocks to restore their inventories in dollar terms, the impulse sensitivity of strategy 3 related to inventory is higher for low-price stocks.

A similar effect can be seen in the impulse sensitivity of strategy 3 related to “Cumulative Order Imbalance”. It is higher for low-price stocks, because higher number of shares is required to implement a particular trading strategy.

5.2. Cross Sectional Analysis

Table 9 presents the coefficient estimates of our cross sectional regression analysis. Coefficient of relative tick is negative and significant. Specialist participation to the trades increases as stock price increases. Hence, consistent with Seppi (1997), specialists participation increases for high price stocks because undercutting the LOB is less costly.

Estimated coefficient of the "Percentage Quoted Spread" provides a related result. As the percentage spread increases, the specialist has more price points to choose from, and accordingly his participation increases.

5.3. Are the participation strategies of the specialists to the trades informative about future price changes?

By using the TORQ database, Harris and Panchapagesan (2005) show that the LOB is informative about the future price movements, and that specialists use this information while making trading decisions. During the period of TORQ database the tick size was equal to \$1/8, and after decimalization the strategies of the specialists have changed considerably.[60]

We use a direct method to test if the specialist's trades are informative about future price changes. Specifically, we estimate the following model by using OLS for each security i and for each side of the market (i.e. buy-side and sell-side):

$$R_{i,t+k} = \alpha_i + \beta_{0,i} R_{i,t-k} + \beta_{1,i} SpPart_{i,t} + \varepsilon_{i,t} \qquad (2)$$

where subscript t denotes arrival time of the market order, $R_{i,t+k}$ is the transaction price return in basis points over k periods starting at time t, $R_{i,t-k}$ is the transaction price

[60] See Coughenour and Harris (2003).

return in basis points over k periods ending at time t, $SpPart_{i,t}$ is a signed dummy variable that is equal to 1, if the specialist chooses strategy 2 or 3 for case 1, and is equal to 1 if the specialist chooses strategy 3 for cases 2, 3 and 4, and zero otherwise, and it is multiplied by -1 if the incoming market order is a buy order and $\varepsilon_{i,t}$ is the random error term. The definition of $SpPart_{i,t}$ implies that, a positive estimated coefficient indicates a correct prediction of the future returns by the specialist. k equals 5 minutes, 1 hour or 1 day. The model captures the predictive power of the trades that the specialists have participated over different time horizons. We include the lagged return to model return mean reversion in short horizon transaction price returns documented in the previous literature.

Table 10 reports the results from estimating equation (2) for all quote cases. For the first three quote cases, interestingly, the number of correct predictions increases as the time horizon increases except for Case 4. The highest percentage of success for predicting future returns is for quote case 4, short-term (5 minutes) returns. The specialist has positive depth in the posted quotes for this case, which might be an indication that the specialist has already predicted the direction of future price changes and added depth to the relevant side of the posted quote.[61] In addition, the size of the market order is less then the depth coming from the LOB. So the specialist has to undercut the LOB if he wants to trade. Therefore, if the specialist has some depth in the current posted quotes and if he undercuts the LOB to be able to trade with coming market order, probably he has some strong predictions about the direction of short-term price changes.

[61] Koksal (2005a) shows that the participation of specialists in the posted quotes has some predictive power over future stock returns, this power being stronger for short-term returns.

Overall, the specialists are not very successful in predicting future returns. Panel B of Table 10 shows that, overall success of specialist in predicting future returns is around 50%. Some specialists, however, are more successful in predicting future returns than others. The results from individual regressions (not reported) show that there are some specialists who can predict the future returns correctly over all time horizons.

6. Conclusion

Using 2001 NYSE system order data in the decimal pricing environment, we analyze how the specialists react to the changes in market variables while making participation decisions to the trades. We analyze the following options that are available to the specialist before he trades: don't participate; participate at the quoted price; participate and improve the price. We find that the specialist uses information in the limit order book as summarized by the limit order book asymmetry. The specialist is more likely to participate to a trade with an arriving market order, if he can step in front of the LOB. If the relative size of the market order, as described by the ratio of the market order size to the posted depth at the relevant side of the market, is high, the specialist chooses not to participate and let the market order trade with the limit order book. Consistent with the theoretical results in the previous literature, specialists trade more aggressively when the spread is large. We find that specialist trading strategies in stocks from different volume and price categories vary substantially. Finally, there is evidence that the specialists trade selectively to manage their inventories.

References

Admati, Anat R., and Paul Pfleiderer, 1989, Divide and Conquer: A Theory of Intraday and Day-of-the-Week Mean Effects, *Review of Financial Studies* 2, 189-223.

Barclay, Michael J., and Jerold B. Warner, 1993, Stealth Trading and Volatility: Which Trades Move Prices?, *Journal of Financial Economics* 34, 281-305.

Boehmer, Ekkehart, Gideon Saar, and Lei Yu, 2003, Lifting the Veil: An Analysis of Pre-Trade Transparency at the NYSE, *NYSE working Paper* Paper #: 2003-01.

Bondarenko, Oleg, and Jaeyoung Sung, 2003, Specialist participation and limit orders, *Journal of Financial Markets* 6, 539-571.

Coughenour, Jay F., and Lawrence E. Harris, 2003, Specialist Profits and Minimum Price Increment, *Working Paper, University of Delaware*.

Dupont, Dominique, 2000, Market Making, Prices, and Quantity Limits, *Review of Financial Studies* 13, 1129-51.

Easley, David, and et al., 1996, Liquidity, Information, and Infrequently Traded Stocks, *Journal of Finance* 51, 1405-36.

Easley, David, Nicholas M. Kiefer, and Maureen O'Hara, 1997, One Day in the Life of a Very Common Stock, *Review of Financial Studies* 10, 805-35.

Easley, David, and Maureen O'Hara, 1992, Time and the Process of Security Price Adjustment, *Journal of Finance* 47, 576-605.

Ellul, Andrew, Craig W. Holden, Pankaj Jain, and Robert Jennings, 2004, A Comprehensive Test of Order Choice Theory: Recent Evidence from the NYSE, *Working Paper, Indiana University*.

Engle, Robert F., and Jeffrey R. Russell, 1998, Autoregressive Conditional Duration: A New Model for Irregularly Spaced Transaction Data, *Econometrica* 66, 1127-62.

Harris, Larry, 2003. *Trading and Exchanges: Market Microstructure for Practitioners* (Oxford University Press).

Harris, Lawrence E., and Venkatesh Panchapagesan, 2005, The information content of the limit order book: evidence from NYSE specialist trading decisions, *Journal of Financial Markets* 8, 25-67.

Harris, Lawrence, and Venkatesh Panchapagesan, 2003, The Information-Content of the Limit Order Book: Evidence from NYSE Specialist Trading Decisions, *Working Paper, Washington University*.

Hasbrouck, Joel, 1992, Using the TORQ Database, *Working Paper, New York University*.

Hasbrouck, Joel, and George Sofianos, 1993, The Trades of Market Makers: An Empirical Analysis of NYSE Specialists, *Journal of Finance* 48, 1565-93.

Kavajecz, Kenneth A., 1999, A Specialist's Quoted Depth and the Limit Order Book, *Journal of Finance* 54, 747-71.

Kavajecz, Kenneth A., and Elizabeth R. Odders-White, 2001, An Examination of Changes in Specialists' Posted Price Schedules, *Review of Financial Studies* 14, 681-704.

Koksal, Bulent, 2004, Participation Strategy of the NYSE Specialists to the Posted Quotes, *Working Paper, Indiana University*.

Koksal, Bulent, 2005a, Participation Strategy of the NYSE Specialists to the Posted Quotes, *Working Paper, Indiana University*.

Kyle, Albert S., 1985, Continuous Auctions and Insider Trading, *Econometrica* 53, 1315-35.

Lee, Charles M. C., and Mark J. Ready, 1991, Inferring Trade Direction from Intraday Data, *Journal of Finance* 46, 733-46.

Madhavan, Ananth, and Seymour Smidt, 1993, An Analysis of Changes in Specialist Inventories and Quotations, *Journal of Finance* 48, 1595-1628.

Madhavan, Ananth, and George Sofianos, 1998, An Empirical Analysis of NYSE Specialist Trading, *Journal of Financial Economics* 48, 189-210.

Panchapagesan, Venkatesh, 2000, Identifying Specialist Trades in the TORQ Data --- A Simple Algorithm, *Working Paper, Washington University*.

Peterson, Mark, and Erik Sirri, 2002, Order Submission Strategy and the Curious Case of Marketable Limit Orders, *Journal of Financial and Quantitative Analysis* 37, 221-41.

Ready, Mark J., 1999, The Specialist's Discretion: Stopped Orders and Price Improvement, *Review of Financial Studies* 12, 1075-1112.

Seppi, Duane J., 1997, Liquidity Provision with Limit Orders and a Strategic Specialist, *Review of Financial Studies* 10, 103-50.

Sofianos, George, and Ingrid M. Werner, 2000, The trades of NYSE floor brokers, *Journal of Financial Markets* 3, 139-176.

Stoll, Hans R., 1978, The Supply of Dealer Services in Securities Markets, *Journal of Finance* 33, 1133-51.

Tables

Table 1. Percentage participation by the NYSE specialists to the posted quotes

This table reports the percentage of bid side and ask side position of the specialists for the stocks in our sample according to volume and price categories. If mean daily volume (mean price) of a stock is higher than the median, then it is in "high" category, otherwise it is in "low" category. The three possible cases for the posted quotes are: LOB alone, LOB+Specialist, and Specialist alone. S_A and S_B denotes the depth contributed by the specialist to the posted bid and ask quotes, respectively. Similarly, L_A and L_B denotes the depth contributed by the LOB to the posted bid and ask quotes, respectively. The numbers in the rows sum up to 100% subject to rounding error.

Volume Categories	**LOB Alone**	**LOB+Specialist**	**Specialist Alone**
Bid-Side of the posted quotes	**$S_B=0; L_B>0$**	**$S_B>0; L_B>0$**	**$S_B>0; L_B=0$**
High	76.98	7.48	15.54
Low	64.61	3.61	31.78
Ask-Side of the posted quotes	**$S_A=0; L_A>0$**	**$S_A>0; L_A=0$**	**$S_A>0; L_A=0$**
High	71.34	9.71	18.95
Low	66.58	3.57	29.85

Price Categories	**LOB Alone**	**LOB+Specialist**	**Specialist Alone**
Bid-Side of the posted quotes	**($S_B=0; L_B>0$)**	**($S_B>0; L_B>0$)**	**($S_B>0; L_B=0$)**
High	71.93	6.96	21.11
Low	80.28	6.49	13.23
Ask-Side of the posted quotes	**$S_A=0; L_A>0$**	**$S_A>0; L_A=0$**	**$S_A>0; L_A=0$**
High	65.47	10.01	24.51
Low	80.04	6.02	13.93

Table 2. Specialist's available choices for different cases.

This table reports possible quote cases at the time a market sell (buy) order of size M_S (M_B) arrives to the specialist. S_B and L_B are the contributions to the posted depth from the specialist and limit order book, respectively (similar for posted ask). Possible strategies of the specialist are 1 (Do not participate), 2 (Participate at the quoted price), and 3 (Participate and improve the price) depending on the quote condition.

Possible Decisions

Posted Bid Depth Size = S_B+L_B

Posted Ask Depth Size = S_A+L_A

1. Do not participate.

2. Participate at the quoted price.

3. Participate and improve the price.

Bid Side Quote Condition	Case	Size of the Incoming Market Sell (M_S)	Possible Decisions
$S_B=0$; $L_B>0$	1	$M_S > L_B$	1,2,3
	2	$M_S \leq L_B$	1,3
$S_B>0$; $L_B>0$	3	$M_S > L_B$	2,3
	4	$M_S \leq L_B$	1,3
$S_B>0$; $L_B=0$	5	$M_S > S_B$	No Decision
	6	$M_S \leq S_B$	No Decision

Ask Side Quote Condition	Case	Size of the Incoming Market Buy (M_B)	Possible Decisions
$S_A=0$; $L_A>0$	1	$M_B > L_A$	1,2,3
	2	$M_B \leq L_A$	1,3
$S_A>0$; $L_A>0$	3	$M_B > L_A$	2,3
	4	$M_B \leq L_A$	1,3
$S_A>0$; $L_A=0$	5	$M_B > S_A$	No Decision
	6	$M_B \leq S_A$	No Decision

Table 3. Multinominal Logit Model Results for stock by stock estimation for Quote Case 1

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Available strategies of the specialist are as follows: 1 (Do not participate), 2 (Participate at the quoted price), and 3 (Participate and improve the price). Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns report the percentage of significant variables at the stated levels of significance. All coefficient estimates for explanatory variables with a * are multiplied by 100000. Strategy 1 is the base case. Significance column in Panel B reports the percentage of significant impulse sensitivities at 5% level of significance. Panel C reports the percentage of negative and positive significant coefficients.

Panel A. Mean Regression Coefficient Estimates

	Strategies		Overall Significance (%)	
Exogenous Variables	**Str2**	**Str3**	**5% sig.**	**10% sig.**
Cumulative Order Imbalance*	2.455	3.441	15.05	24.73
Excess Spread	0.019	0.194	82.80	83.87
Medium Trade Dummy	-0.263	-0.522	19.35	32.26
Trade Idle Time	-0.026	-0.130	10.75	17.20
Relative Order Size	-0.314	-0.603	69.89	78.49
LOB Asymmetry*	0.022	-0.005	15.05	21.51
Near LOB Asymmetry*	-0.201	0.112	6.45	8.60
Order Type Dummy	0.308	-0.281	20.43	29.03
Specialist's Inventory*	0.229	0.807	23.66	33.33
Volatility	-0.034	-1.817	9.68	20.43

Panel B. Mean Impulse Sensitivities (%)

	Available Strategies			Significance (%)		
Exogenous Variables	**Str1**	**Str2**	**Str3**	**Str1**	**Str2**	**Str3**
Cumulative Order Imbalance	-2.62	0.83	1.83	94.57	91.30	94.57
Excess Spread	-5.07	-0.35	5.54	96.74	90.22	98.91
Medium Trade Dummy	1.23	-0.95	-0.29	94.57	96.74	89.13
Trade Idle Time	-0.36	0.42	-0.05	94.57	94.57	94.57
Relative Order Size	6.27	-4.17	-2.15	96.74	96.74	93.48
LOB Asymmetry	-0.72	0.38	0.35	91.30	92.39	91.30
Near LOB Asymmetry	-0.83	0.59	0.24	94.57	92.39	86.96
Order Type Dummy	-2.23	2.60	-0.38	93.48	94.57	94.57
Specialist's Inventory	-2.70	1.04	1.70	95.65	91.30	94.57
Volatility	0.22	0.02	-0.25	96.74	94.57	94.57

Panel C. Signs of Significant Impulse Sensitivities in Percentages

	Str1		Str2		Str3	
Exogenous Variables	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**
Cumulative Order Imbalance	72.41	27.59	44.05	55.95	29.89	70.11
Excess Spread	92.13	7.87	54.22	45.78	2.2	97.8
Medium Trade Dummy	31.03	68.97	66.29	33.71	64.63	35.37
Trade Idle Time	63.22	36.78	39.08	60.92	45.98	54.02
Relative Order Size	0	100	91.01	8.99	96.51	3.49
LOB Asymmetry	50	50	51.76	48.24	53.57	46.43
Near LOB Asymmetry	63.22	36.78	37.65	62.35	48.75	51.25
Order Type Dummy	68.6	31.4	22.99	77.01	70.11	29.89
Specialist's Inventory	75	25	34.52	65.48	37.93	62.07
Volatility	33.71	66.29	63.22	36.78	58.62	41.38

Table 4. Multinominal Logit Model Results for stock by stock estimation for Quote Case 2

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Available strategies of the specialist are as follows: 1 (Do not participate), and 3 (Participate and improve the price). Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns report the percentage of significant variables at the stated levels of significance. All coefficient estimates for explanatory variables with a * are multiplied by 100000. Strategy 1 is the base case. Significance column in Panel B reports the percentage of significant impulse sensitivities at 5% level of significance.

Panel A. Mean Regression Coefficient Estimates

	Strategies	Significance (%)	
Exogenous Variables	**Str3**	**5% sig.**	**10% sig.**
Cumulative Order Imbalance*	5.17	24.55	32.73
Excess Spread	0.16	91.82	91.82
Medium Trade Dummy	-0.34	35.45	40.00
Trade Idle Time	0.15	34.55	46.36
Relative Order Size	-0.13	51.82	58.18
LOB Asymmetry*	-0.15	30.00	35.45
Near LOB Asymmetry*	0.12	16.36	20.91
Order Type Dummy	-0.34	25.45	32.73
Specialist's Inventory*	1.30	35.45	45.45
Volatility	-0.19	25.45	32.73

Panel B. Mean Impulse Sensitivities (%)

	Available Strategies		Significance (5 %)	
Exogenous Variables	**Str1**	**Str3**	**Str1**	**Str3**
Cumulative Order Imbalance	-2.67	2.67	96.33	96.33
Excess Spread	-10.85	10.85	99.08	99.08
Medium Trade Dummy	0.84	-0.84	94.50	94.50
Trade Idle Time	-1.46	1.46	100.00	100.00
Relative Order Size	2.28	-2.28	98.17	98.17
LOB Asymmetry	0.55	-0.55	97.25	97.25
Near LOB Asymmetry	-0.66	0.66	97.25	97.25
Order Type Dummy	0.85	-0.85	95.41	95.41
Specialist's Inventory	-2.78	2.78	95.41	95.41
Volatility	0.42	-0.42	99.08	99.08

Panel C. Signs of Significant Impulse Sensitivities in Percentages

	Str1		Str3	
Exogoneous Variables	**Neg**	**Pos**	**Neg**	**Pos**
Cumulative Order Imbalance	78.1	21.9	21.9	78.1
Excess Spread	98.15	1.85	1.85	98.15
Medium Trade Dummy	43.69	56.31	56.31	43.69
Trade Idle Time	85.85	14.15	14.15	85.85
Relative Order Size	12.84	87.16	87.16	12.84
LOB Asymmetry	43.93	56.07	56.07	43.93
Near LOB Asymmetry	47.17	52.83	52.83	47.17
Order Type Dummy	23.08	76.92	76.92	23.08
Specialist's Inventory	68.27	31.73	31.73	68.27
Volatility	41.67	58.33	58.33	41.67

Table 5. Multinominal Logit Model Results for stock by stock estimation for Quote Case 3

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Available strategies of the specialist are as follows: 2 (Participate at the quoted price), and 3 (Participate and improve the price). Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression, which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns report the percentage of significant variables at the stated levels of significance. All coefficient estimates for explanatory variables with a * are multiplied by 100000. Strategy 2 is the base case. Significance column in Panel B reports the percentage of significant impulse sensitivities at 5% level of significance.

Panel A. Mean Regression Coefficient Estimates

Specialist Buy (Market Sell)	**Strategies**	**Significance (%)**	
Exogenous Variables	**Str3**	**5% sig.**	**10% sig.**
Cumulative Order Imbalance*	1.64	16.39	22.95
Excess Spread	0.33	77.05	80.33
Medium Trade Dummy	0.11	6.56	14.75
Trade Idle Time	-0.02	4.92	11.48
Relative Order Size	-0.75	50.82	62.30
LOB Asymmetry*	0.02	9.84	16.39
Near LOB Asymmetry*	0.03	9.84	18.03
Order Type Dummy	-0.68	16.39	26.23
Specialist's Inventory*	0.40	4.92	13.11
Volatility	0.01	13.11	19.67

Table 5. cont'd

Panel B. Mean Impulse Sensitivities (%)

	Available Strategies		Significance (5 %)	
Exogenous Variables	**Str2**	**Str3**	**Str2**	**Str3**
Cumulative Order Imbalance	-5.45	5.45	93.44	93.44
Excess Spread	-21.73	21.73	93.44	93.44
Medium Trade Dummy	-2.08	2.08	91.80	91.80
Trade Idle Time	-1.38	1.38	91.80	91.80
Relative Order Size	9.31	-9.31	86.89	86.89
LOB Asymmetry	-3.06	3.06	85.25	85.25
Near LOB Asymmetry	-1.08	1.08	88.52	88.52
Order Type Dummy	3.63	-3.63	86.89	86.89
Specialist's Inventory	-4.14	4.14	83.61	83.61
Volatility	-1.91	1.91	90.16	90.16

Panel C. Signs of Significant Impulse Sensitivities in Percentages

	Str2		Str3	
Exogoneous Variables	**Neg**	**Pos**	**Neg**	**Pos**
Cumulative Order Imbalance	64.91	35.09	35.09	64.91
Excess Spread	100	0	0	100
Medium Trade Dummy	57.14	42.86	42.86	57.14
Trade Idle Time	44.44	55.56	55.56	44.44
Relative Order Size	3.57	96.43	96.43	3.57
LOB Asymmetry	56.6	43.4	43.4	56.6
Near LOB Asymmetry	44.23	55.77	55.77	44.23
Order Type Dummy	26.42	73.58	73.58	26.42
Specialist's Inventory	62.75	37.25	37.25	62.75
Volatility	36.36	63.64	63.64	36.36

Table 6. Multinominal Logit Model Results for stock by stock estimation for Quote Case 4

In Panel A, we report the mean of estimated coefficients from logistic regressions that converged. In Panel B, we report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable. Available strategies of the specialist are as follows: 1 (Do not participate), and 3 (Participate and improve the price). Overall significance in Panel A comes from "Type III Analysis of Effects" table produced by SAS logistic regression which gives the Wald Chi-square statistic for the effect of an explanatory variable. Overall significance columns report the percentage of significant variables at the stated levels of significance. All coefficient estimates for explanatory variables with a * are multiplied by 100000. Strategy 1 is the base case. Significance column in Panel B reports the percentage of significant impulse sensitivities at 5% level of significance.case

Panel A. Mean Regression Coefficient Estimates

Specialist Buy (Market Sell)	Strategies	Significance (%)	
Exogenous Variables	**Str3**	**5% sig.**	**10% sig.**
Cumulative Order Imbalance*	4.32	14.49	26.09
Excess Spread	0.23	62.32	75.36
Medium Trade Dummy	-0.13	11.59	20.29
Trade Idle Time	-0.03	11.59	14.49
Relative Order Size	0.48	26.09	36.23
LOB Asymmetry*	0.05	11.59	20.29
Near LOB Asymmetry*	-0.11	13.04	15.94
Order Type Dummy	-0.14	14.49	21.74
Specialist's Inventory*	1.90	14.49	20.29
Volatility	-3.54	17.39	24.64

Table 6. cont'd

Panel B. Mean Impulse Sensitivities (%)

	Available Strategies		Significance (5 %)	
Exogenous Variables	**Str1**	**Str3**	**Str1**	**Str3**
Cumulative Order Imbalance	-1.74	1.74	91.18	91.18
Excess Spread	-6.59	6.59	94.12	94.12
Medium Trade Dummy	0.57	-0.57	91.18	91.18
Trade Idle Time	-0.57	0.57	92.65	92.65
Relative Order Size	-2.97	2.97	83.82	83.82
LOB Asymmetry	-1.51	1.51	85.29	85.29
Near LOB Asymmetry	-1.62	1.62	91.18	91.18
Order Type Dummy	-0.23	0.23	97.06	97.06
Specialist's Inventory	-0.65	0.65	91.18	91.18
Volatility	1.32	-1.32	89.71	89.71

Panel C. Signs of Significant Impulse Sensitivities in Percentages

	Str1		Str3	
Exogenous Variables	**Neg**	**Pos**	**Neg**	**Pos**
Cumulative Order Imbalance	69.35	30.65	30.65	69.35
Excess Spread	98.44	1.56	1.56	98.44
Medium Trade Dummy	41.94	58.06	58.06	41.94
Trade Idle Time	67.74	32.26	32.26	67.74
Relative Order Size	73.02	26.98	26.98	73.02
LOB Asymmetry	54.39	45.61	45.61	54.39
Near LOB Asymmetry	60.34	39.66	39.66	60.34
Order Type Dummy	31.82	68.18	68.18	31.82
Specialist's Inventory	51.61	48.39	48.39	51.61
Volatility	22.95	77.05	77.05	22.95

Table 7. Logit Model Results for stock by stock estimation according to volume categories

This table reports report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable from logistic regressions that converged for all quote cases by volume categories. If mean daily volume of a stock is above the median, then it is in the high-volume category, otherwise it is in the low-volume category.

		Quote Case 1			Quote Case 2		Quote Case 3		Quote Case 4	
Variable	Vol. Cat.	Str1	Str2	Str3	Str1	Str3	Str2	Str3	Str1	Str3
Cumulative Order Imbalance	H	-1.59	0.47	1.13	-2.16	2.16	-5.76	5.76	-1.10	1.10
	L	-3.84	-0.18	4.02	-3.58	3.58	-1.98	1.98	-4.72	4.72
Excess Spread	H	-4.15	-1.67	5.82	-8.82	8.82	-22.46	22.46	-5.84	5.84
	L	-7.98	3.30	4.68	-14.48	14.48	-13.60	13.60	-10.11	10.11
Medium Trade Dummy	H	0.58	-0.43	-0.15	-0.30	0.30	-2.33	2.33	0.03	-0.03
	L	2.61	-1.88	-0.72	2.87	-2.87	0.74	-0.74	3.12	-3.12
Relative Order Size	H	5.55	-3.24	-2.31	1.64	-1.64	9.50	-9.50	-1.83	1.83
	L	9.00	-7.37	-1.62	3.44	-3.44	7.15	-7.15	-8.32	8.32
LOB Asymmetry	H	-0.52	0.10	0.42	-0.48	0.48	-2.78	2.78	-1.93	1.93
	L	1.20	-1.31	0.11	2.41	-2.41	-6.17	6.17	0.45	-0.45
Near LOB Asymmetry	H	-0.85	0.69	0.17	0.26	-0.26	-0.88	0.88	-0.25	0.25
	L	-1.60	1.12	0.48	-2.31	2.31	-3.36	3.36	-8.02	8.02
Trade Idle Time	H	-0.70	0.64	0.06	-1.56	1.56	-1.75	1.75	-0.72	0.72
	L	-0.10	0.51	-0.41	-1.26	1.26	2.79	-2.79	0.15	-0.15
Order Type Dummy	H	-1.49	1.96	-0.47	0.84	-0.84	3.83	-3.83	0.53	-0.53
	L	-4.50	4.59	-0.08	0.88	-0.88	1.41	-1.41	-3.77	3.77
Specialist's Inventory	H	-3.08	1.58	1.49	-1.40	1.40	-3.96	3.96	-0.44	0.44
	L	-1.94	-0.38	2.32	-5.27	5.27	-6.23	6.23	-1.61	1.61
Volatility	H	1.87	-1.54	-0.32	1.22	-1.22	-2.63	2.63	0.70	-0.70
	L	-1.13	1.15	-0.03	-1.02	1.02	6.21	-6.21	4.21	-4.21

Table 8. Logit Model Results for stock by stock estimation according to price categories

This table reports report the mean impulse sensitivities defined as the change in the probability of an event caused by a one standard deviation shock in the explanatory variable from logistic regressions that converged for all quote cases by price categories. If mean daily price of a stock is above the median, then it is in the high-price category, otherwise it is in the low-price category.

		Quote Case 1			Quote Case 2		Quote Case 3		Quote Case 4	
Variable	Price. Cat.	Str1	Str2	Str3	Str1	Str3	Str2	Str3	Str1	Str3
Cumulative Order Imbalance	H	-1.75	0.65	1.10	-1.95	1.95	-1.58	1.58	-1.70	1.70
	L	-2.65	-0.14	2.80	-3.49	3.49	-11.41	11.41	-1.80	1.80
Excess Spread	H	-5.10	-1.19	6.29	-10.42	10.42	-22.35	22.35	-6.38	6.38
	L	-5.06	0.50	4.56	-11.34	11.34	-20.77	20.77	-6.96	6.96
Medium Trade Dummy	H	0.52	-0.48	-0.04	0.38	-0.38	-3.45	3.45	0.65	-0.65
	L	1.80	-1.18	-0.62	1.35	-1.35	0.04	-0.04	0.43	-0.43
Relative Order Size	H	5.73	-3.32	-2.41	1.49	-1.49	9.31	-9.31	-2.59	2.59
	L	7.27	-5.47	-1.80	3.19	-3.19	9.31	-9.31	-3.63	3.63
LOB Asymmetry	H	-0.36	-0.30	0.66	0.21	-0.21	-3.70	3.70	-0.14	0.14
	L	0.23	-0.18	-0.06	0.94	-0.94	-2.07	2.07	-3.87	3.87
Near LOB Asymmetry	H	-0.87	0.65	0.21	-0.38	0.38	0.03	-0.03	-1.33	1.33
	L	-1.25	0.97	0.28	-0.97	0.97	-2.80	2.80	-2.12	2.12
Trade Idle Time	H	-0.36	0.45	-0.10	-1.58	1.58	-0.20	0.20	-1.06	1.06
	L	-0.82	0.81	0.00	-1.31	1.31	-3.19	3.19	0.27	-0.27
Order Type Dummy	H	-2.10	2.51	-0.41	0.50	-0.50	2.51	-2.51	-0.35	0.35
	L	-2.39	2.72	-0.33	1.26	-1.26	5.37	-5.37	-0.02	0.02
Specialist's Inventory	H	-2.22	1.04	1.18	-2.32	2.32	-0.07	0.07	-1.00	1.00
	L	-3.56	1.19	2.37	-3.31	3.31	-10.42	10.42	-0.05	0.05
Volatility	H	1.55	-1.22	-0.34	0.65	-0.65	-1.38	1.38	1.31	-1.31
	L	0.59	-0.45	-0.14	0.15	-0.15	-2.72	2.72	1.34	-1.34

Table 9. OLS Results from Cross-sectional Regression of Specialist Participation

This table reports results from estimation of equation 1. Standard errors are reported in parentheses. ** and * denotes significance levels at the 1% and 5% levels, respectively. Dependent variable is the percentage of trades that the specialist has chosen strategy 2 (participate at the quoted price) or strategy 3 (participate at the improved price).

Exogenous Variables	**Coefficients**	
Intercept	0.480	**
	(0.099)	
Log Mean Daily Volume	-0.016	
	(0.016)	
Log Market Capitalization	0.004	
	(0.013)	
Relative Tick	-14.103	*
	(7.916)	
Volatility (Std. Dev. of Transaction Prices)	-0.064	
	(0.045)	
Average Percentage Quoted Spread	6.738	**
	(2.703)	
Sample Size	114	
Adj R2	0.28	

Table 10. Time Series Regression of Future Returns

Panel A reports results from estimation of equation 2 for each of the 148 stocks in our sample. For each future return regression (k=5 minutes, 1 hour, or 1 day), mean and standard error of all coefficient estimates across stocks are reported. The last two columns report the number of significant positive and negative coefficients. A positive coefficient of specialist participation to the trades indicates that the specialist predicts the future return correctly. Panel B reports the percentage of correct predictions for each quote case.

Panel A. Distiribution of the coefficient estimates

	Quote Case 1				Quote Case 2				Quote Case 3				Quote Case 4			
	Mean	Std. Error	Neg.	Pos.	Mean	Std. Error	Neg.	Pos.	Mean	Std. Error	Neg.	Pos.	Mean	Std. Error	Neg.	Pos.
Variables	**k = 5 minutes**				**k = 5 minutes**				**k = 5 minutes**				**k = 5 minutes**			
Intercept	-0.79	5.34	63	48	-0.74	4.94	55	62	0.13	5.59	38	50	-2.55	9.41	57	31
Lagged Return	0.03	0.19	52	59	0.03	0.15	46	71	0.00	0.27	46	42	0.11	1.04	43	45
Specialist Participation	-1.32	7.62	62	49	-1.06	5.96	64	53	-0.62	15.36	51	37	2.86	9.56	30	58
	k = 1 hour				**k = 1 hour**				**k = 1 hour**				**k = 1 hour**			
Intercept	-7.99	30.43	71	49	-8.64	31.82	74	57	-11.26	36.14	58	31	-14.49	35.00	61	25
Lagged Return	-0.03	0.19	68	52	-0.03	0.19	78	53	-0.06	0.22	55	34	-0.02	0.21	45	41
Specialist Participation	-0.68	36.14	62	58	-1.37	24.56	64	67	11.20	82.87	43	46	5.68	32.17	37	49
	k = 1 day				**k = 1 day**				**k = 1 day**				**k = 1 day**			
Intercept	-6.97	166.86	52	72	-8.97	159.42	51	81	-25.76	219.75	40	49	-17.07	173.25	39	49
Lagged Return	-0.16	0.28	89	35	-0.15	0.24	98	34	-0.23	0.28	70	19	-0.24	0.28	71	17
Specialist Participation	-5.14	119.83	57	67	-2.71	61.01	58	74	21.41	139.99	40	49	10.94	105.26	41	47

Panel B. Percentage of correct predictions

k	QC1	QC2	QC3	QC4
5 minutes	44%	45%	42%	66%
1 hour	48%	51%	52%	57%
1 day	54%	56%	55%	53%

Appendix A

Information about the sample that consists of 143 stocks we employ to compare specialist strategies.

Symbol	Data Period	Symbol	Data Period	Symbol	Data Period	Symbol	Data Period
AIG	x	FMO	xx	MRK	x	SZ	xx
ALS	xx	FNM	x	MU	x	T	x
AOT	xx	FOE	xx	MWC	xx	TGT	x
AP	xx	FTD	xx	MWD	x	TLM PRB	xx
AVB	xx			MXE	xx	TMK	x
AXP	x	GGT PR	xx	NAP	xx	TRP	xx
AXP PRA	xx	GLW	x	NKE	x	TYC	x
BAC	x	GNA	xx	NOK	x	UBT	xx
BBV	xx	GPS	x	NPC	xx	UDS	x
BK	x	GPT	x	NR	xx	UMG PRY	xx
BKE	xx	GRP	xx	NUI	xx	USI	xx
BPL	xx	GX	x	OFG	xx	VIAB	x
BRM	xx	HD	x	OMX	xx	VOD	x
BZL	xx	HI PRT	xx	ONE	x	VTP	xx
C	x	HIF	xx	OUI	xx	WB	x
CB	x	HPT	xx	PBR	xx	WFC	x
CBA	xx	HRC	x	PCG	x	WMK	xx
CHH	xx	HWP	x	PCS	x	WMS	xx
CLP PRA	xx	IBM	x	PFE	x	WMT	x
CM	xx	IMY	xx	PFP	xx	XOM	x
CMS	x	IRT	xx	PNK	xx	XRX	x
CNC	x	JBL	x	PP	xx	ZNH	xx
CPN	x	JPM	x	PST PRA	xx	ZNT	xx
CQB PRA	xx	JPM PRC	xx	PTM	xx	ZQK	xx
CSD PRA	xx	JW B	xx	Q	x	ZTR	xx
CUZ	xx	KGC	xx	RI	xx		
CWF	xx	KM	x	RKY	x		
DIS	x	KWD	xx	ROM PR	xx		
DL	xx	LMGA	x	SBC	x		
DRE	xx	LNC PRG	xx	SBP PRA	xx		
DRE PRA	xx	LNC PRY	xx	SCH	x		
DUC	xx	LTD	x	SGP	x		
EIX	x	MC	xx	SJI	xx		
ELY	x	MCD	x	SJR	xx		
ENE PRT	xx	MER	x	SKO	xx		
EQT	x	MIJ	xx	SLR	x		
F	x	MKT	xx	SQM A	xx		
FCP	xx	MO	x	SSS PRB	xx		
FIG PRA	xx	MOT	x	SUS	xx		

x : 04/02/2001 - 04/06/2001
xx: 04/02/2001 - 06/29/2001

Chapter 3

Differences in Performances and Strategies of the Individual NYSE Specialists

Abstract

This paper shows that there exist differences in the performances of *individual* specialists in terms of the execution costs and participation strategies to the posted quotes and trades. We find that quoted and effective spreads, quoted depth, order-imbalance halt use and number of trades that receive price improvement differ significantly across individual specialists. The explanatory power of the model as measured by adjusted R^2 increases when we include the individual specialist dummies. Evidence suggests that differences across specialist firms documented in the previous literature are largely due to the differences in individual specialists. Similar to Cao, Choe and Hatheway (1997) who study the NYSE in 1993, we find evidence for a subsidy from active stocks to inactive stocks in 2001. We find that, as the trading frequency increases, order processing costs increase for both the specialist firms and individual specialist portfolios which implies that profits from active stocks subsidize inactive stocks. We also show that individual NYSE specialists differ significantly in their participation strategies to the posted quotes and trades. This suggests that there are significant differences in execution costs (spreads, depths, etc.) between specialists because they use different strategies.

1. Introduction

New York Stock Exchange (NYSE) specialists are responsible for making markets for the stocks assigned to them. Their primary obligation is to ensure that there exists a fair and orderly market in their stocks. They should be willing to trade when other traders are unwilling to trade and the bid-ask spread should not be too wide. In addition, the specialists should intervene to prevent large price jumps, and create price continuity.[62] The NYSE uses the average width of the quoted bid-ask spread, the average depth of the quotes, the number of large price jumps, and the average size of price reversals to evaluate specialists' performances. The specialists' also have negative obligations that restrict their trading. Specialists cannot trade for their own accounts if there exist public orders at the same price or better. In addition, they should not trade with limit orders in order not to take the liquidity available to public traders. [63]

Specialists may have some market power in their stocks but they are greatly constrained by competition from limit order trades and floor brokers. If there are differences in execution qualities of stocks of different specialists, this implies that some investors pay higher transaction costs simply because a certain specialist oversees the stock that they want to trade. In their analysis of NYSE specialist firms, for example, Cao, Choe and Hatheway (1997) estimate that differences in execution costs among specialist firms can be over $4.1 million per year.[64] Barnea (1974) is one of the earliest

[62] For a detailed description of the specialists' functions, see Rule 104 (Dealings by Specialists) in NYSE (1999).

[63] See Harris (2003) p.494 for an extensive description of specialists' roles and how they can act against the interests of the public investors on the NYSE.

[64] They estimate that effective spreads for 90th and 10th percentile specialist firms differ by 2.04 cents. Based on an average daily volume of 68,600 shares across the 23 stocks assigned to the 90th percentile specialist firm in their data, they calculate the cost difference as 1.02 cents x 68,600 shares/day x 256days x 23 stocks = $4,120,000

papers that observes a specialist effect on the size of the bid-ask spread. Corwin (1999) finds that spreads, depth, transitory volatility, frequency and duration of order-imbalance halts are different across specialist firms. Coughenour and Deli (2002) find that some of these differences can be attributed to the organizational form of the specialist firms. This paper contributes to the existing literature by showing that there exist differences in the performances of *individual* specialists in terms of the execution costs of their stocks and by providing possible explanations for these differences.

Analyzing the differences in individual specialists is very important because it helps us understand how the specialist contributes to various dimensions of market performance. On the NYSE, the dollar value of average monthly trading volume that the specialists oversee was $968.18 billion and average specialist volume as percentage of the NYSE total volume was around 20% in 2004.[65] The NYSE specialists oversee this huge trading activity and there are potential conflict of interests between the specialists desire to make profits for themselves and their obligation to be fair to all public traders. There has been an important debate going on about the role of the specialists and whether their contributions are valuable in the overall trading activity. Recently, because of an investigation by the U.S. Securities and Exchange Commission into floor trading practices, five largest specialist firms at the New York Stock Exchange were required to pay a combined $241.8 million to settle charges of improper trading.[66] The NYSE claims

[65] See "Market Activity" in the NYSE fact book that can be found at http://www.nysedata.com/factbook/. Generally, the specialist participation rate mentioned in the literature is the specialist volume as percent of NYSE 2x total volume which was approximately 10% in 2004. If one wants to calculate the total volume that the specialists traded for their own accounts, specialist volume as percent of NYSE total volume is the correct figure to use.

[66] See for example, "NYSE to Punish Five Specialists In Trading Inquiry", *Wall Street Journal* (October 16, 2003). More recently, *New York Times* (February 7, 2005) reported that Manhattan United States attorney's office was probing whether individual traders on New York Stock Exchange floor cheated

that the investors get the best available price most of the time in the specialist system. However, many institutional investors prefer faster executions and they believe that the human-based system for auctioning stocks unnecessarily slows down the trade execution process.[67] To address these concerns, the NYSE is planning to allow investors to execute more stock orders automatically.[68]

In this study, we find that quoted and effective spreads, quoted depth, order-imbalance halt use and number of trades that receive price improvement differ significantly across individual specialists. The explanatory power of the model as measured by the adjusted R^2 increases when we include the individual specialist dummies, but this increase is small. We find that differences across specialist firms documented in the previous literature are largely due to the differences in individual specialists.

Similar to the findings in Cao, Choe and Hatheway (1997) who study NYSE in 1993, we find evidence for a subsidy from active stocks to inactive stocks in 2001. We find that, as the trading frequency increases, order processing costs increase for both the specialist firms and individual specialist portfolios which implies that profits from active stocks subsidize inactive stocks.

By using the sample and methodology used by Koksal (2005a) and Koksal (2005b), we show that individual NYSE specialists also differ significantly in their

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customers through executing proprietary orders before customer orders and getting involved in trade that should be carried out automatically with no intervention

[67] See "Fidelity Urges NYSE to Revamp Trading Operation", *Wall Street Journal*, October 14, 2003.
[68] See "NYSE's Automatic Transition", *Wall Street Journal*, June 22, 2004 and NYSE Newsletter August 2004 issue on http://www.nyse.com.

participation in the posted quotes and trades.[69] This explains the differences in execution costs (spreads, depths etc) between specialists. There are significant differences between individual specialists because they use different strategies.

The rest of the article is organized as follows. Section 1 discusses the alternative specialist performance measures. Section 2 discusses the variables that we use to analyze the differences in individual specialists' strategies. The samples and data used to analyze the performances and strategies of the specialists are described in Section 3. Section 4 presents the empirical methodology and results. Section 5 concludes.

2. Measures of Specialist Performance

As discussed in Cao, Choe and Hatheway (1997), under the assumption of perfect competition, only the most efficient specialist firms that make zero economic profits would exist in the market. A rejection of the null hypothesis that there are no significant differences between specialists imply that there are significant differences in the costs of doing business and/or specialist profits.

Following Corwin (1999) and Cao, Choe and Hatheway (1997), we use the log of the following variables to analyze the differences in performances of individual specialists:

- Percentage Quoted Spread,
- Percentage Effective Spread based on national best bid and offer,
- Percentage Effective Spread based on NYSE posted bid and offer,
- Total Quoted Share Depth,

[69] The sample and methodology employed in Koksal (2005a) and Koksal (2005b) are discussed in Section 4 below.

- Total Quoted Dollar Depth,
- Percentage Price improvement,
- Order processing costs.

2.1. Quotes, Spreads, and Depths

Posted quotes and spreads are directly related to two important dimensions of liquidity: size and cost. Liquidity is essential for well functioning markets. As discussed before, two of the variables that the NYSE uses to evaluate specialist performances are the average width of the quoted bid-ask spread and the average depth of the quotes. Accordingly, we use the log of the following variables to compare the performances of the specialists.

Percentage Quoted Spread is the ratio of the posted spread to the quote midpoint, i.e.,

$$Percentage\ Quoted\ Spread = \frac{Ask - Bid}{(Ask + Bid)/2}$$

where *Ask* and *Bid* are the ask and bid quotes posted by the NYSE specialist, respectively. We then calculate the mean percentage quoted spread for each stock for each day by averaging daily intraday quotes.[70] Therefore, our sample has one observation for each stock for each day. Quoted spread is simply the round-trip cost of a trade, when the trader buys at the ask and sells at the bid.

When a transaction takes place inside the quotes, the round-trip cost of the trade is less than the quoted spread. In this case, the difference between execution price and the

[70] We use equally weighted averages to calculate our measures. Another possibility is to use time-weighted averages, which gives more weight to those spreads that have longer durations.

posted quote is called as price improvement and the round-trip cost of a trade is equal to the effective spread. We calculate the percentage effective spread by using two definitions of midpoint as follows:

$$Percentage\,Effective\ Spread = 2 * \frac{\left| Price - Midpoint \right|}{Midpoint},$$

where *Price* is the transaction price and *Midpoint* is either the average of the best bid and best ask or the average of the posted bid and ask quotes 15 seconds prior to the trade.[71] Then we calculate the mean percentage effective spread for each stock for each day by averaging over daily transactions during the sample period. Similar to Corwin (1999), we define the percentage of price-improved trades as:

$$Percentage\,Price\,Improvement = \frac{Number\ of\ \ Price\ Improved\ Trades}{Total\ Number\ of\ Trades}.$$

To determine the price improved trades, we use the best bid and offer as the benchmark rather than the posted quotes. A trade receives price improvement if it is executed within the national best bid and offer.

Another measure related to the liquidity of a stock is the depth at the posted quotes. We calculate the total depth as:

$$Total\,Quoted\,Depth = Posted\,Bid\,Depth + Posted\ Ask\,Depth$$

and calculate the mean total quote depth for each stock for each day by averaging daily intraday depths.

Using this measure might be problematic, because for high-price stocks, the specialist is risking more capital if he is using his own inventory. That is, if two

[71] The first study that finds that trades are often reposted with a lag is Lee and Ready (1991). Hasbrouck, Sofianos and Sosebee (1993) report a median lag of 14 seconds for a sample of 144 stocks over the first five trading days in November 1990. Following Corwin (1999), we use a 15 seconds rule.

specialists are posting the same depth, *cet. par.*, the specialist of the stock with higher price is providing more liquidity. To account for the dollar value of the depth that the specialist posts, we also calculate:

$$Dollar\ Value\ of\ the\ Total\ Depth = (Posted\ Bid\ Depth \times Bid) + (Posted\ Ask\ Depth \times Ask)$$

and calculate daily averages for each stock.

2.2. Execution Costs and Intersecurity Subsidization

The order processing cost component of the bid ask spread can be used to identify differences in the business costs of providing liquidity among the specialists. Cao, Choe and Hatheway (1997) find that there are significant differences in order processing costs among specialist firms. They also find that order processing or noninformational costs of trading are higher for actively traded stocks in their sample that covers the period from March 1, 1993 to May 31, 1993.[72] They interpret their results as to mean that actively traded stocks subsidize inactive stocks in the portfolios of specialist firms.

Order processing costs include both the costs of doing business and the specialist profits. Under the assumption of perfect competition, only the most efficient specialist firms that make zero economic profits would exist in the market. A rejection of the null hypothesis that there are no significant differences between specialists imply that there are significant differences in the costs of doing business and/or specialist profits. Gibson, Singh and Yerramilli (2003) find that the decline in spreads after the decimalization was caused by the decrease in the order processing cost component of the spread. The dollar value of the adverse information and inventory costs did not change significantly because

[72] The coefficient of "the number of trades" is positive in the regressions where the dependent variable is the order processing cost component of the bid-ask spread.

of the decimalization. As the authors suggest, this is probably because of the decline in excess specialist profits. Hence, if we find significant differences in order processing costs between specialists by using 2001 data from the trading environment in decimalization, it will be safer to attribute the differences in the order processing costs to the differences in the efficiency of the specialists. By using our NYSE post-panel data from the decimal trading environment, we analyze whether there are differences in terms of order processing costs between individual specialists and whether there is inter-security subsidization within both the specialist firms' and individual specialists' portfolios.

We calculate the order processing cost for each stock by using the method described in Huang and Stoll (1997). Huang and Stoll (1997) show that price changes for a stock can be modeled as follows:

$$P_t - P_{t-1} = \frac{S}{2}(Q_t - Q_{t-1}) + (\alpha + \beta)\frac{S}{2}Q_{t-1} + e_t, \quad (1)$$

where P_t is the stock price at time t, S is the constant spread, Q_t is a trade indicator where $Q_t = 1$ if the trade at t is buyer-initiated and occurs above the midpoint, -1 if the trade is seller initiated and occurs below the midpoint, and 0 if the trade is at the quote midpoint, α is the adverse information and β is the inventory cost components of the bid-ask spread, and e_t is the error term. $\phi \equiv 1-(\alpha+\beta)$ is the order processing component of the bid-ask spread which is an estimate of the costs of doing business. We

use the estimated value of ϕ from these regressions as the dependent variable in our second stage regressions.[73]

3. Measures of Specialist Strategies

The previous section showed that there are important differences between individual NYSE specialists. In this section, we analyze if there are differences between the specialists' participation in the posted quotes and trades.

3.1. Net Specialist Participation to the Posted Quotes

The posted quotes reflect trading interests of the limit order traders, floor brokers and the specialist; therefore, we need to estimate the LOB to separate the portion of the posted depth coming from the LOB. The LOBs are estimated by using the method described in Kavajecz (1999). First, the LOB at the beginning of the sample period is estimated by searching for all execution and cancellation records that refer to orders placed before the sample period. Second, the initial LOB and each of the subsequent LOBs are updated sequentially depending on the placed orders, executions and cancellations. The result is the estimate of the LOBs at each point in time. After the LOBs have been estimated, the LOB bid (ask) depth is subtracted from the posted bid (ask) depth if the posted bid (ask) price is the same as the best limit bid (ask) price. The *residual* depth comes from the specialist's trading interest and the orders left by the floor brokers with the specialist for the specialist to execute (passive floor broker participation). We define this residual as the "specialist's participation in the posted

[73] To estimate the order processing cost component in a reliable manner, we require that a stock has at least 20 trades per day to be included in the sample for the second stage regressions.

quotes" and calculate the total percentage specialist participation to analyze the differences in participation strategies of the individual specialists in the quotes.[74]

For each quote revision, a specialist has the following choices: He may choose not to participate and let the posted quotes reflect the prices and depths on the LOB (0% contribution in the posted quotes from the specialist); he may add depth to the LOB at the best prices on the book (mixed case, specialist percentage contribution is positive and less than 100%); and he may undercut the LOB which implies that the posted quotes fully reflect the trading interest of the specialist (100% contribution from the specialist). Accordingly, to investigate if the specialists participate in the quotes differently, we partition the posted depth into the specialist's contribution and the LOB's contribution as described above, and define the percentage contribution of the specialists in the posted quotes as follows:

$$Total\ Percentage\ Specialist\ Participation = \frac{\left(\overline{\left(\frac{Specialist\ Bid\ Depth}{Total\ Bid\ Depth}\right)} + \overline{\left(\frac{Specialist\ Ask\ Depth}{Total\ Ask\ Depth}\right)}\right)}{2}$$

where bars denote equally weighted daily averages over the sample period (to be described in Section 5 below).

3.2. Specialist Participation to the Trades

We apply the method used by Harris and Panchapagesan (2005) and Koksal (2005b). When a market order arrives, the specialist faces the decision of choosing between the following strategies:

[74] Our dataset does not allow us to split out the passive floor broker participation.

4. Do not participate,

5. Participate at the quoted price,

6. Participate and improve the price.[75]

We define our measure of specialist participation in the trades as follows:

$$Percentage\ Specialist\ \ Participation\ to\ the\ Trades = \frac{Number\ of\ \ Strategy\ 2 + Number\ of\ \ Strategy\ 3}{Total\ Number\ of\ Trades}$$

4. Data

4.1. Analysis of Specialist Performance

We use the NYSE's Post-Panel data for 2001 to identify the stocks traded by each individual specialist. Our regressions related to the analyses in Section 1.1 and Section 1.3 use the data from March 2001. We obtain intraday quote and trade data from NYSE's TAQ database. We use the CRSP database to identify the type of stocks in our sample.[76]

We have to include a large number of specialist dummies in our regressions and we need a large sample size. In addition, the specialist of a stock can change for various reasons.[77] As a result, we cannot use the averages of our variables over the whole sample period because some stocks are not assigned to the same specialist for the whole sample period. Therefore, we calculate daily values of all variables.

[75] In their analysis of specialist trading decisions, Harris and Panchapagesan (2003) add one more case which is to "stop the order". The percentage of orders in our sample that are stopped is around 0.01%. Accordingly, we exclude this choice from our analysis.
[76] See the variable definitions in Section 3 below.
[77] It is less likely that the specialist *firm* of a stock changes. Since we identify individual specialist by using post-panels, we assume that each post-panel remained within the same firm during our sample period

We only use quotes from normal trading environment.[78] In addition, a quote or a trade is eliminated if for the current quote

i. the effective spread is greater than $2.00,

ii. bid or ask is equal to zero,

iii. quoted spread is negative.

In addition, to estimate the daily order processing costs by using equation (1) in a reliable manner, we require that the number of trades for that day is greater than 20. In our final sample, we have daily data for stocks traded by 462 individual specialists employed by 19 specialist firms.[79]

Table 1 reports the descriptive statistics for the dependent and independent variables for each specialist firm. In Panel A, we do not see any pattern in the dependent variables across the specialist firms, as many of these variables are normalized. Average quoted and effective spread for all firms is 18 cents and 12 cents, respectively. Average total quoted depth at the bid and ask is 4,762.24. In addition, 38.17% of the trades receive price improvement. Larger firms that employ greater number of specialists seem to provide more dollar depth. We observe from results in Table 1, Panel A that there is some variation between specialist firms which was formally shown to exist by Corwin (1999) and Cao, Choe and Hatheway (1997).

4.2. Analysis of Specialist Strategies

We employ the sample used by Koksal (2005a) to calculate the percentage specialist participation in the posted quotes and trades. Because of the volume of the data, it is

[78]These quotes have the quote mode 12 in the NYSE TAQ database. This restriction implies that we exclude opening and closing quotes, and quotes during regulatory or non-regulatory halts.

[79] As of April 2005, there are seven specialist firms because of the continued consolidation. See Hatch and Johnson (2002) for an analysis of specialist firm acquisitions on market quality

necessary to select a sub sample of NYSE-listed securities. The original sample was selected as follows: Initially, 50 most actively traded NYSE stocks during the 20 trading days prior to January 29, 2001 were chosen. In addition, 25 stocks from each of the four Volume-Price groups were randomly selected. To pick the 100-stock random sample, NYSE-listed securities were ranked by share trading volume and, separately, by the average NYSE trade price during the 20 trading days prior to January 29, 2001. Each security was placed into one of the four categories after comparing its share price to the median NYSE share price and its trading volume to the median NYSE volume. These groups (of unequal numbers of stocks) are a high-volume/high-price group, a high-volume/low-price group, a low-volume/high-price group, and, a low-volume/low-price group. Within each group, securities were arranged alphabetically (by symbol), and every Nth security was selected, where N was chosen to select 25 securities from that group. Because two of the 50 stocks with the highest trading volume were also randomly chosen as part of the high volume groups, the final sample has 148 securities.

The NYSE's SOD dataset gives detailed information on the entry and processing of orders. Order data include the name of the security, order type, a buy-sell indicator, order size, order date and time, limit price (if the order is a limit order), and the identity of the member firm submitting the order. Execution data include the date and time of each trade, the execution price, the number of shares executed, and cancellation information. Orders, executions and cancellations are time-stamped to the second.

Because of the size of the dataset, we estimate the LOBs for active stocks using one week of data (April 2nd ,2001 – April 6th, 2001) only. For the rest of the stocks we

estimate the LOBs using three months of data (April 2nd, 2001 – June 29th, 2001). See the appendix for the symbols and the data periods for each stock used in the analysis.

5. Empirical Methodology and Results

5.1. Analysis of Specialist Performance

In this section, we investigate if there exist differences in performances of the individual NYSE specialists in terms of the liquidity they provide, and execution costs after controlling for stock characteristics. Specifically, following Cao, Choe and Hatheway (1997) and Corwin (1999), we estimate the following regression model for each specialist firm separately:

$$DepVar_{it} = \alpha_0 + \sum_{j=2}^{N} \alpha_j D_{j,it} + \beta_1 Log(NTrade)_{it} + \beta_2 Log(TradeSize)_{it} + \beta_3 Log(MarketCap)_{it} \quad (2)$$

$$+ \beta_4 Volatility_{it} + \beta_5 Log(QuoteMidpoint)_{it} + \beta_6 Regional_{it} + \beta_8 Fund_{it} + \beta_9 Foreign_{it} + \varepsilon_{it}$$

where the subscript i refers to the ith stock, t refers to time (day), N is the number of individual specialists for a given specialist firm and *DepVar* is the log of average daily percentage quoted spread, log of average daily percentage effective spread based on NBBO or NYSE bid and ask prices, log of average daily total quoted depth, average daily dollar value of the total depth, daily percentage of trades that receive price improvement, and the log of proportion of order processing costs in the quoted spread;

D_j is the individual specialist dummy variable

LogNTrade is the log of the number of daily trades;

logTradeSize is the log of average daily share volume per trade on the NYSE;

logMarketCap is log of the mean daily price times shares outstanding;

Volatility is the coefficient of variation of transaction prices over a given day;

LogQuoteMidpoint is the log of average daily quote midpoints;

Regional is the percentage of trades executed on the regional exchanges;

Fund is a dummy variable that equals to one if the stock is a Unit, REIT, or closed-end fund;

Foreign is a dummy variable that equals to one if the stock is a foreign security.

We estimate equation 2 for each specialist firm separately to control for the specialist firm characteristics. The level of capital available for individual specialist use may have significant effects on the dependent variable. In addition, both Cao, Choe and Hatheway (1997) and Corwin (1999) show that there exist significant differences between specialist firms. Analyzing each specialist firm separately provides the cleanest results to analyze the differences between individual specialists.

5.1.1. Quotes, Spreads, and Depths

Table 2 through Table 7 report the OLS results for the quote, spread, and depth variables for each specialist firm. The distributions of the estimated coefficients of individual specialist dummy variables are also reported. Number of trades and trade size are negatively related to the spread measures and positively related to the total quoted share depth and dollar depth. For active stocks, specialists face strong competition from limit order traders. In addition, they can spread the fixed costs of market making over more volume and they face less inventory risk because managing the inventory is easier. Therefore, as the number of trades and trade size increase, we see smaller spreads and larger quoted depths.

As the number of trades and trade size increase, we see fewer price improvements because when the bid and ask prices are very close to the market's estimate of the true value of the stock (the spread is small in active stocks), it is less profitable to undercut the bid and/or ask prices.

Risks of highly volatile assets cause spreads to be wider and depths to be smaller. Also high volatility and larger spreads make price improvement easy.

Log of the quote midpoint has negative coefficients in spread and total quoted share depth and a positive coefficient in the price improvement and total quoted dollar depth regressions. As stock price increases, the tick size is less binding and undercutting posted quotes is less costly which increases the number of trades that receive price improvement.[80] Since one of the variables that the NYSE uses to evaluate specialists' performances is the average share depth of the quotes, as stock price increases, the dollar value of the posted depth increases for high price stocks.

The F-statistic in Panel A of Tables 2-7 is for the joint hypothesis that there exist no significant differences between individual specialists after controlling for stock characteristics. This null hypothesis is rejected for all regressions indicating that individual NYSE specialists post significantly different quotes and depths. In addition, the proportion of trades that receive price improvement is significantly different across individual specialists. The increase in adjusted R^2s provide further evidence that adding the individual specialist dummies increase the explained variation in the dependent variables, but this increase is small. We also perform F-test for all pairs of estimated

[80] See Harris (1994) for the arguments why smaller tick size could cause smaller spreads and smaller displayed depth. Seppi (1997) shows that specialist profits are maximized as the tick size approaches to zero. Consistent with this result, Koksal (2005a) finds higher specialist participation in posted quotes for high price stocks which might also cause narrower spreads for stocks with high quote midpoints (high prices).

specialist dummies. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. Overall, rejection rate is high, implying that results are robust to our arbitrary choice of the excluded specialist

Panel B of Tables 2 to 7, reports the economic significance of the differences between specialists. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. In Table 2, Panel B, for example, "Average percentage quoted spread" and "average quote midpoint" are the average of percentage quoted spread and quote midpoint for each specialist firm. "Average dollar spread" is calculated by multiplying "average percentage quoted spread" and "average quote midpoint". "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 \cdot e^b$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in $" is calculated by multiplying "average dollar spread" by "mean deviation in %".

“Mean deviation in %” ranges from a low of -33.15 % to a high of 38.60 %. This implies that the economic significance of the differences between specialists is large. These numbers in percentage terms translate to a range of -11 cents to 9 cents difference in quoted spreads between individual specialists employed by the same firm.

The economic magnitude of the differences between specialists can be large for investors. The magnitude of this difference in dollar terms can be estimated by using the estimated differences between specialists in percentage effective spreads. Table 3, Panel B reports the results for the percentage effective spread calculated by using the national best bid and offer.[81] The mean deviation between specialists in percentages ranges from -32.22 % to 31.48 %. In dollar terms, this range is from -7 cents to 5 cents. The real difference, however, depends on the daily volume handled by each specialist firm. We multiply the difference in effective spreads by average daily volume from Table 1, and report the results in the last column of Table 3, Panel B. The daily estimated difference to investors range from a low of -$31,751.68 to a high of $24,188.62, with a mean value of -$1,350.23. The range for the estimated difference in spreads for the 21 trading days in March 2001 is from -$666,785.37 to $507,960.96. Our analysis use data from March 2001, so it is difficult to estimate the yearly differences. But above figures suggest that, the differences between individual specialists can have significant economic implications for the investors.

Table 5, Panel B reports the differences between specialists in terms of the share depth that they post. The mean deviation in shares range from -1,529.35 shares to 1,557.45. These differences in shares may not be a good indicator of the differences between specialists in terms of the capital they risk, because that depends on the stock price. Mean deviation in dollar depth is reported in Panel B of Table 6. The range of the estimated differences between specialists in terms of the dollar depth they provide at the bid and ask is from -$24,160.74 to $32,287.88.

[81] The results reported in Panel B of Table 4, and related interpretations for percentage effective spread which is based on the NYSE quotes are similar.

Finally, Panel B of Table 7 reports that mean deviation from average price improvement ranges from -8.38% to 8.31%. In addition, the increases in adjusted R2s after we include individual specialist dummies are larger for percentage price improvement.

The results so far provide evidence that there are significant differences between individual specialists. To see if the differences between specialist firms documented in the previous literature are because of the differences between individual specialists or not, we run pooled regressions. First, we estimate a base model where only the firm specific dummies are included. Then we estimate a full model where we add individual specialist dummies. The results from these regressions are reported in Table 8. In Table 8, we report the estimates and significance of specialist firm dummies, adjusted R^2s, and test results where the null is the equality of specialist firm dummy coefficients before and after we add individual specialist firm dummies. Consistent with the previous results, adding the individual specialist dummies improve the predictive power of the model as reflected by the increases in adjusted R^2s. However, the null hypothesis that there are no significant differences between specialist firms is rejected for both the base model and the full model. Therefore, we conclude that, some of the differences between specialist firms documented in the previous literature stems from the differences between the individual specialists they employ, but there are other factors that determine these differences as well.

5.1.2. Execution Costs and Intersecurity Subsidization

Table 9 reports results from estimating equation (2) where the dependent variable is the log of order processing cost for each stock estimated by equation (1). The number of trades has a positive coefficient similar to what is found by Cao, Choe and Hatheway (1997) based on 1993 data. This is consistent with the hypothesis that active stocks subsidize inactive stocks. Order processing costs decrease with the price level; estimated coefficients for quote midpoint generally have negative coefficients. Finally, order-processing costs are higher for Units, REITs, and closed-end funds.

When we include the individual specialist dummies to the model, the adjusted R^2 increases for almost all firms, providing evidence that the individual specialists have significant impact on costs of the trade. In addition, the null hypothesis of no difference between specialists is strongly rejected for all but four firms. 101 of the 309 specialist dummies are significant at the 5% level. Estimated coefficients of the individual specialist dummies range from -1.01 to 0.696 with a mean value of -0.077. Negative coefficients imply that the specialists add value by lowering the order processing cost, but this is not true for all specialists as we see from the distribution of estimated coefficients.

Next, we examine whether active stocks subsidize inactive stocks within specialist firms' and individual specialists' stocks. Cao, Choe and Hatheway (1997) find that for their sample, when they regress the order processing cost on variables related to stock characteristics, they find that the coefficient of trading frequency (number of trades) is positive for 37 of the 40 specialist firms. They argue that their results may be an evidence of subsidy from liquid stocks to illiquid stocks.[82] To see if this negative

[82] See also, Huang and Liu (2004).

relationship between order processing costs and the trading frequency within specialist firms' and individual specialists' portfolios, we run a regression similar to the one used by Cao, Choe and Hatheway (1997). Specifically, we estimate the following model for each specialist firm and for each individual specialist portfolio.

$$\phi_{it} = \alpha + \beta_1 Log(NTrade)_{it} + \beta_2 Log(TradeSize)_{it} + \beta_3 Log(MarketCap)_{it} \quad (3)$$
$$+ \beta_4 Volatility_{it} + \beta_5 Log(QuoteMidpoint)_{it} + \beta_6 Regional_{it} + \varepsilon_{it}$$

where the subscript i refers to the ith stock for the specialist firm or for the portfolio of the individual specialist and t for time. The independent variables are defined as in equation (2).

The results from estimating equation (3) for each specialist firm are reported in Table 10. Following Cao, Choe and Hatheway (1997), we only report the coefficient estimates for the number of trades. The estimated β_1 is positive for 20 of the 21 specialist firms. Among 20 positive coefficients, 13 of them are significant at the 0.1% level and 5 of them are significant at the 1% level. The t-statistic for the mean of the estimated coefficients is 4.45, which is significant at the 0.1% level. This supports the results reported in Table 9. Order processing costs increase as the trading frequency increases within each specialist firm. This finding is consistent with the hypothesis that active stocks subsidize inactive stocks and supports the results found by Cao, Choe and Hatheway (1997).

To see if intersecurity subsidization occurs within the portfolios of individual specialists, we estimate equation (3) for each individual specialist's portfolio. Table 11, Panel A reports the distribution of the estimated β_1s for all individual specialist

portfolios. The results strongly suggest a positive relationship between the number of trades and order processing costs, i.e., the fixed costs (order processing costs) of doing business increase as the number of trades increase. The mean (median) for all and significant coefficients are 0.09 (0.08) and 0.12 (0.11), respectively. The t-statistic for the mean of all (significant) estimated coefficients is 17.39 (19.90), which is significant at the 0.1% level. The histograms of the estimated coefficients are shown in Table 11 Panels B and C. 304 of the 339 estimated coefficients are positive and 231 of the 242 coefficients significant at the 10% level are positive.

Our results provide evidence that the specialists subsidize inactive stocks in 2001 by increasing order processing cost component of the bid-ask spread for more active stocks. This suggests that specialists cover their fixed costs for illiquid stocks by charging higher spreads for active stocks.

5.2. Analysis of Specialist Strategies

We estimate the following model by OLS:

$$DepVar_{it} = \alpha_0 + \sum_{j=1}^{340} \alpha_j D_{j,it} + \beta_1 Log(NTrade)_{it} + \beta_2 Log(TradeSize)_{it} + \beta_3 Log(MarketCap)_{it} \quad (4)$$

$$+ \beta_4 Volatility_{it} + \beta_5 Log(QuoteMidpoint)_{it} + \varepsilon_{it}$$

where the subscript i refers to the ith stock, t refers to the time (trading day), *DepVar* is the percentage specialist participation in the quotes and trades as defined in Section 4, and the dependent variables are as defined in Section 3. We calculate equally weighted daily averages for each of the dependent and independent variables to estimate equation (4).

5.2.1. Net Specialist Participation to the Posted Quotes

The results about percentage specialist participation in the quotes are presented in Table 12. The signs and significance of the explanatory variables are robust to adding individual specialist dummies.

The results for other exogenous variables are consistent with the findings of Koksal (2005a). As the number of trades increases, specialists tend to decrease their participation, because specialist services are needed more in illiquid stocks. There is a negative relationship between the average trade size and specialist participation in the quotes. As the trade size increases, specialists decrease their participation in current quotes, because when they add depth to the quotes, their strategies are constrained by their position in the quotes. If large trades are more likely to come from the informed trades, then there is less specialist participation for the stocks with a larger average trade size. We observe higher specialist participation for more volatile stocks, which is consistent with the price-smoothing obligation of the specialists. Also we observe higher specialist participation for high-price (measured by quote midpoint) stocks; as discussed in Koksal (2005a), the tick size is less binding and undercutting the LOB is less costly for high-price stocks. Therefore, it may be more profitable to participate in the quotes for high-price stocks.

The F-statistic for the null hypothesis is 23.8 and it is significant at the 0.1% level. Therefore, there exist strong differences between individual specialists in their participation in the quotes. As we expect, the explanatory power of the model increases significantly, from 0.2278 to 0.5396, after we include the individual specialist dummy variables. This larger increase in adjusted R^2 when compared to spread and depth

regressions suggests that there is more idiosyncratic variation in specialist quote participation policy than in their other policies.

The results of this section explain why we observe the differences in quotes and spreads as discussed in Section 3.1. This is because the specialists implement different strategies while participating in the posted quotes. The difference between specialists is significant even after controlling for stock characteristics such as trading volume, volatility and the trading frequency.

5.2.2. Specialist Participation to the Trades

In this section, we analyze the participation strategies of individual specialists to the trades following a market order arrival. The results from estimating equation (4) are reported in Table 13. The adjusted R^2 increases from 0.1398 to 0.2875 after the individual specialist dummy variables are included.

We observe a negative relationship between the number of transactions and aggressiveness of trades made by specialists. As the number of trades decreases, it becomes more likely that the specialists participate in a trade at the quoted or improved price. Similar to the results of section 6.1, this behavior is consistent with the specialist obligation to be ready to trade when no one else is willing to trade. Our finding might also imply that it is more profitable to participate to the trades in illiquid stocks.

As the trade size increases, specialists are more likely to let the market order trade with the LOB, since this would protect them from the possibility of informed trading. Consistent with their obligation to stabilize prices, the specialists are more likely to participate in the trades for more volatile stocks.

The F-statistic for the joint hypothesis that there are no significant differences between individual specialists after controlling for stock characteristics equals 8.5584, which is significant at the 0.1% level. Therefore, there are significant differences between specialists when they have to decide whether to take the other side of an incoming market order. These results explain why we observe, for instance, significant differences between the levels of price improvements for stocks controlled by different specialists. Indeed, the differences are likely to arise because the specialists employ different strategies.

6. Conclusion

This paper shows that there exist differences in the performances of *individual* specialists in terms of the execution costs and participation strategies to the posted quotes and trades. We find that the quoted and effective spreads, quoted depth, and number of trades receiving price improvement differ significantly across individual specialists. The explanatory power of the model as measured by the adjusted R^2 increases when individual specialist dummies are included. Our findings suggest that the differences across specialist firms documented in the previous literature are largely due to the differences in individual specialists.

We find a positive relationship between order processing costs and the trading frequency for both the specialist firms and individual specialist portfolios. This finding supports the results found by Cao, Choe and Hatheway (1997) that profits from active stocks subsidize inactive stocks.

We show that individual NYSE specialists differ significantly in their participation in the posted quotes and trades. This explains the differences in the execution costs (spreads, depths, etc.) between the specialists.

References

Barnea, Amir, 1974, Performance Evaluation of New York Stock Exchange Specialists, *Journal of Financial and Quantitative Analysis* 9, 511-35.

Cao, Charles, Hyuk Choe, and Frank Hatheway, 1997, Does the Specialist Matter? Differential Execution Costs and Intersecurity Subsidization on the New York Stock Exchange, *Journal of Finance* 52, 1615-40.

Corwin, Shane A., 1999, Differences in Trading Behavior across NYSE Specialist Firms, *Journal of Finance* 54, 721-45.

Coughenour, Jay F., and Daniel N. Deli, 2002, Liquidity Provision and the Organizational Form of NYSE Specialist Firms, *Journal of Finance* 57, 841-69.

Gibson, Scott, Rajdeep Singh, and Vijay Yerramilli, 2003, The Effect of Decimalization on the Components of the Bid-Ask Spread, *Journal of Financial Intermediation* 12, 121-48.

Harris, Larry, 2003. *Trading and Exchanges: Market Microstructure for Practitioners* (Oxford University Press).

Harris, Lawrence E., 1994, Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes, *Review of Financial Studies* 7, 149-78.

Harris, Lawrence, and Venkatesh Panchapagesan, 2003, The Information-Content of the Limit Order Book: Evidence from NYSE Specialist Trading Decisions, *Working Paper, Washington University*.

Harris, Lawrence, and Venkatesh Panchapagesan, 2005, The Information-Content of the Limit Order Book: Evidence from NYSE Specialist Trading Decisions, *Journal of Financial Markets* forthcoming.

Hasbrouck, Joel, George Sofianos, and Deborah Sosebee, 1993, New York Stock Exchange Systems and Trading Procedures, *NYSE Working Paper* #93-01.

Hatch, Brian C., and Shane A. Johnson, 2002, The Impact of Specialist Firm Acquisitions on Market Quality, *Journal of Financial Economics* 66, 139-67.

Huang, Roger D., and Jerry W. Liu, 2004, Do Individual NYSE Specialists Subsidize Illiquid Stocks?, *University of Notre Dame, Working Paper*.

Huang, Roger D., and Hans R. Stoll, 1997, The Components of the Bid-Ask Spread: A General Approach, *Review of Financial Studies* 10, 995-1034.

Kavajecz, Kenneth A., 1999, A Specialist's Quoted Depth and the Limit Order Book, *Journal of Finance* 54, 747-71.

Koksal, Bulent, 2005a, Participation Strategy of the NYSE Specialists to the Posted Quotes, *Working Paper, Indiana University*.

Koksal, Bulent, 2005b, Participation Strategy of the NYSE Specialists to the Trades, *Working Paper, Indiana University*.

Lee, Charles M. C., and Mark J. Ready, 1991, Inferring Trade Direction from Intraday Data, *Journal of Finance* 46, 733-46.

McFadden, Daniel, 1974, The Measurement of Urban Travel Demand, *Journal of Public Economics* 3, 303-328.

NYSE, 1999. *New York Stock Echange, INC. Constitution and Rules* (CCH Incorporated, Chicago, IL).

Seppi, Duane J., 1997, Liquidity Provision with Limit Orders and a Strategic Specialist, *Review of Financial Studies* 10, 103-50.

Tables

Table 1. Descriptive Statistics

Panels A and B report the mean values of the dependent and independent variables. For each stock, mean value of each variable per day is calculated. The average each variable is then calculated for each specialist firm. Market capitalization is calculated by multiplying mean daily price of each stock by the number of shares outstanding. Volatility is the coefficient of variation of the daily prices.

Panel A. Dependent Variables

Specialist Firm	No	Number of Specs	% Quoted Spread	Quoted Spread	% Effective Spread (NBBO)	% Effective Spread (NYSE)	Effective Spread (NYSE)	Total Quoted Share Depth	Total Quoted Dollar Depth	% of Price Improved Trades
Labranche And Co.	1	82	0.81	0.21	0.57	0.57	0.11	5,492.00	110,199.0	38.01
Spear, Leeds And Kellogg Spec. Llc	2	73	0.95	0.16	0.61	0.62	0.09	4,623.27	105,227.0	38.24
Wagner Stott Mercator Llc	3	68	1.16	0.22	0.75	0.77	0.13	4,860.18	106,680.0	39.88
Fleet Meehan Specialist Inc	4	64	1.00	0.18	0.68	0.69	0.11	4,635.63	96,041.9	37.86
Van Der Moolen Specialist Usa Llc	5	51	1.20	0.17	0.81	0.83	0.11	4,629.23	84,473.9	40.15
Rpm Specialist Corp.	6	17	0.92	0.19	0.62	0.62	0.12	4,230.79	97,084.2	37.85
Bear Hunter Specialist Llc	7	16	1.06	0.16	0.72	0.73	0.11	4,835.98	87,305.4	38.44
Walter N. Frank And Co. Llc	8	13	1.31	0.25	0.88	0.88	0.14	5,408.40	85,454.3	34.05
Benjamin Jacobson And Sons Llc	9	12	1.04	0.20	0.74	0.71	0.12	4,366.73	96,313.5	35.60
Performance Specialist Group, L.P.	10	12	1.54	0.18	1.08	1.10	0.13	4,630.32	60,833.4	37.49
Stern And Kennedy	11	10	0.98	0.19	0.68	0.68	0.13	3,601.83	77,673.3	42.19
Bocklet And Co. Llc	12	8	1.12	0.20	0.73	0.73	0.12	4,361.82	89,025.0	39.09
Susquehanna Specialists	13	8	1.15	0.15	0.77	0.78	0.10	5,586.19	91,496.0	36.27
Labranche & Co/Freedom/Adrian & Co	14	6	1.21	0.18	0.85	0.85	0.14	3,704.50	59,853.6	37.54
Lyden, Dolan, Nick & Co.,Llc.	15	6	1.28	0.16	0.81	0.83	0.10	5,410.25	86,048.7	39.80
Scavone,Mc Kenna,Cloud And Co Llc	16	6	1.15	0.23	0.76	0.77	0.13	4,382.10	85,567.3	34.74
Weiskopf, Silver Specialists, Llc	17	5	1.22	0.12	0.89	0.90	0.09	5,865.12	98,624.8	32.98
Freedom Specialists/Adrian/Rpm Spe	18	3	1.16	0.18	0.79	0.80	0.13	4,145.69	71,770.1	38.30
Buttonwood/Albert Fried & Co Llc	19	2	1.55	0.16	0.97	0.99	0.10	5,712.60	81,369.8	46.77
Average			1.15	0.18	0.78	0.78	0.12	4,762.24	87,949.5	38.17

Panel B. Exogenous Variables

Specialist Firm	No	Number of Trades	Mean Daily Trade Size	Average Daily Volume	Market Cap. (Millions)	Volatility	Mean Daily Quote Midpoint	% of Regional Trades	Fund	Foreign
LABRANCHE AND CO.	1	222.07	1,291.47	492,507	6,307.42	0.69	34.99	18.61	0.135	0.037
SPEAR, LEEDS AND KELLOGG SPEC. LLC	2	232.43	1,457.29	409,330	5,042.33	0.77	26.11	17.60	0.182	0.038
WAGNER STOTT MERCATOR LLC	3	199.52	1,343.18	413,846	5,064.19	0.74	26.37	20.48	0.149	0.028
FLEET MEEHAN SPECIALIST INC	4	219.47	1,364.21	414,494	5,975.91	0.73	25.89	18.25	0.162	0.028
VAN DER MOOLEN SPECIALIST USA LLC	5	175.21	1,312.60	375,981	3,872.12	0.78	22.23	18.48	0.198	0.074
RPM SPECIALIST CORP.	6	162.68	1,208.90	255,057	5,152.48	0.62	27.20	18.71	0.114	0.016
BEAR HUNTER SPECIALIST LLC	7	196.16	1,335.38	464,798	4,509.65	0.76	22.87	20.55	0.172	0.047
WALTER N. FRANK AND CO. LLC	8	109.35	1,577.88	202,660	1,458.11	0.74	22.76	18.16	0.255	0.060
BENJAMIN JACOBSON AND SONS LLC	9	213.44	1,172.75	361,104	5,574.53	0.73	25.88	18.86	0.129	0.036
PERFORMANCE SPECIALIST GROUP, L.P.	10	59.50	1,226.46	78,981	863.02	0.78	19.05	19.80	0.309	0.050
STERN AND KENNEDY	11	158.95	1,104.80	261,305	3,541.34	0.62	23.30	16.90	0.309	0.000
BOCKLET AND CO. LLC	12	144.00	1,317.96	223,441	2,998.02	0.78	23.64	16.96	0.180	0.037
SUSQUEHANNA SPECIALISTS	13	162.26	1,383.40	267,884	1,615.87	0.73	20.17	17.48	0.211	0.053
LABRANCHE & CO/FREEDOM/ADRIAN & CO	14	143.38	2,271.41	236,045	1,606.25	0.89	20.45	13.83	0.178	0.061
LYDEN, DOLAN, NICK & CO.,LLC.	15	116.75	1,456.76	187,216	1,577.17	0.80	19.54	20.13	0.231	0.051
SCAVONE,MC KENNA,CLOUD AND CO LLC	16	107.67	1,306.69	171,468	2,925.24	0.65	23.09	18.14	0.223	0.073
WEISKOPF, SILVER SPECIALISTS, LLC	17	60.83	1,213.84	89,464	564.28	0.80	19.28	23.68	0.283	0.037
FREEDOM SPECIALISTS/ADRIAN/RPM SPE	18	117.56	1,195.20	190,861	1,669.79	0.65	21.81	15.40	0.171	0.059
BUTTONWOOD/ALBERT FRIED & CO LLC	19	79.55	1,051.69	76,849	748.99	0.69	21.71	18.45	0.234	0.000
Average		151.62	1,346.94	272,278.32	3,214.04	0.73	23.49	18.45	0.20	0.041

Table 2. Regression Results: Log of Percentage Quoted Spread

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of percentage quoted spread. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Average percentage quoted spread" and "average quote midpoint" are the average of percentage quoted spread and quote midpoint for each specialist firm. "Average dollar spread" is calculated by multiplying "average percentage quoted spread" and "average quote midpoint". "Mean deviation in %" is calculated as follows: If b is the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 xeb$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in $" is calculated by multiplying "average dollar spread" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-1.596 ***	-0.186 ***	-0.067 ***	-0.073 ***	0.230 ***	-0.470 ***	0.089 ***	-0.162 ***	0.209 ***	0.8099	0.8448	25.11	0.000	94.72%
2	-1.154 ***	-0.192 ***	-0.065 ***	-0.092 ***	0.189 ***	-0.495 ***	0.056 *	-0.288 ***	0.025	0.8261	0.8499	19.79	0.000	95.61%
3	-0.413 ***	-0.176 ***	-0.099 ***	-0.153 ***	0.150 ***	-0.415 ***	0.356 ***	-0.458 ***	0.019	0.8063	0.8247	8.08	0.000	78.74%
4	-1.511 ***	-0.222 ***	-0.073 ***	-0.077 ***	0.280 ***	-0.423 ***	0.132 ***	-0.177 ***	0.036	0.8190	0.8466	24.86	0.000	97.14%
5	-0.811 ***	-0.180 ***	-0.082 ***	-0.124 ***	0.260 ***	-0.481 ***	-0.149 ***	-0.353 ***	0.135 ***	0.8345	0.8448	6.97	0.000	70.15%
6	-1.508 ***	-0.227 ***	-0.105 ***	-0.054 ***	0.337 ***	-0.488 ***	0.050	-0.084 **	0.350 ***	0.8309	0.8489	10.52	0.000	75.24%
7	-1.848 ***	-0.188 ***	-0.062 ***	-0.078 ***	0.272 ***	-0.463 ***	0.046	-0.350 ***	-0.129 ***	0.8319	0.8443	14.45	0.000	83.52%
8	-1.365 ***	-0.210 ***	-0.114 ***	-0.057 ***	0.350 ***	-0.514 ***	-0.262 ***	-0.259 ***	-0.040	0.7309	0.7445	7.57	0.000	89.09%
9	-0.984 ***	-0.250 ***	-0.069 ***	-0.142 ***	0.220 ***	-0.282 ***	0.058	-0.532 ***	0.055	0.8347	0.8456	6.77	0.000	86.67%
10	-0.266	-0.193 ***	-0.085 ***	-0.178 ***	0.259 ***	-0.342 ***	0.036	-0.244 ***	0.114 **	0.8009	0.8206	16.83	0.000	100.00%
11	-1.122 ***	-0.177 ***	-0.027	-0.233 ***	0.298 ***	-0.181 ***	0.371 **	-0.289 ***		0.6967	0.7282	5.82	0.000	96.43%
12	-1.765 ***	-0.159 ***	0.012	-0.143 ***	0.215 ***	-0.351 ***	-0.099	-0.230 ***	0.178 ***	0.8603	0.8658	8.54	0.000	46.67%
13	-1.171 ***	-0.173 ***	-0.075 ***	-0.093 ***	0.217 ***	-0.544 ***	-0.034	-0.209 ***	0.136 ***	0.7805	0.7929	15.23	0.000	93.33%
14	-0.015	-0.086 ***	-0.024	-0.260 ***	0.091 ***	-0.410 ***	-0.013	-0.352 ***	-0.081	0.8668	0.8701	3.00	0.019	16.67%
15	-1.619 ***	-0.245 ***	0.016	-0.112 ***	0.285 ***	-0.382 ***	-0.230 ***	-0.218 ***	0.056	0.7972	0.8076	19.48	0.000	100.00%
16	-0.629 ***	-0.128 ***	-0.085 ***	-0.155 ***	0.316 ***	-0.469 ***	-0.107	-0.230 ***	0.048	0.8450	0.8487	1.65	0.159	100.00%
17	-0.423 **	-0.061 ***	-0.041 **	-0.243 ***	0.084 ***	-0.439 ***	0.051	-0.336 ***	0.076	0.8577	0.8721	9.58	0.000	100.00%
18	-0.579	-0.116 ***	-0.105 ***	-0.156 ***	0.350 ***	-0.533 ***	-0.498 **	-0.322 ***	0.100	0.8472	0.8472	1.33	0.250	na
19	0.328	-0.250 ***	-0.176 ***	-0.135 ***	0.297 ***	-0.464 ***	-0.751 ***	-0.851 ***		0.7934	0.8122	53.61	0.000	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates				
Specialist Firm No	**Mean**	**Median**	**Std**	**Min**	**Max**	**Av. % Quoted Spread**	**Av. Quote Midpoint**	**Av. Dollar Spread**	**Mean Deviation in %**	**Mean Deviation in $**
1	-0.288	-0.286	0.182	-0.752	0.076	0.81%	$34.99	$0.28	-25.06%	-$0.07
2	-0.187	-0.206	0.163	-0.572	0.253	0.95%	$26.11	$0.25	-17.01%	-$0.04
3	-0.076	-0.107	0.182	-0.423	0.666	1.16%	$26.37	$0.31	-7.35%	-$0.02
4	-0.184	-0.192	0.167	-0.640	0.244	1.00%	$25.89	$0.26	-16.78%	-$0.04
5	-0.034	-0.042	0.132	-0.315	0.297	1.20%	$22.23	$0.27	-3.32%	-$0.01
6	-0.184	-0.160	0.140	-0.452	0.003	0.92%	$27.20	$0.25	-16.83%	-$0.04
7	0.114	0.106	0.123	-0.080	0.302	1.06%	$22.87	$0.24	12.11%	$0.03
8	-0.001	0.022	0.123	-0.174	0.141	1.31%	$22.76	$0.30	-0.09%	$0.00
9	0.153	0.121	0.213	-0.247	0.514	1.04%	$25.88	$0.27	16.57%	$0.04
10	-0.279	-0.312	0.139	-0.434	0.024	1.54%	$19.05	$0.29	-24.31%	-$0.07
11	0.326	0.297	0.197	0.045	0.642	0.98%	$23.30	$0.23	38.60%	$0.09
12	-0.017	0.026	0.095	-0.216	0.062	1.12%	$23.64	$0.26	-1.66%	$0.00
13	-0.118	-0.126	0.145	-0.315	0.122	1.15%	$20.17	$0.23	-11.14%	-$0.03
14	-0.019	-0.043	0.091	-0.128	0.088	1.21%	$20.45	$0.25	-1.89%	$0.00
15	-0.108	-0.158	0.119	-0.234	0.053	1.28%	$19.54	$0.25	-10.20%	-$0.03
16	-0.120	-0.118	0.046	-0.163	-0.048	1.15%	$23.09	$0.27	-11.27%	-$0.03
17	0.243	0.251	0.087	0.144	0.327	1.22%	$19.28	$0.24	27.52%	$0.06
18	0.058	0.058	0.053	0.021	0.096	1.16%	$21.81	$0.25	5.98%	$0.02
19	-0.403	-0.403	na	-0.403	-0.403	1.55%	$21.71	$0.34	-33.15%	-$0.11
Average	-0.127	-0.144	0.209	-0.752	0.666	1.15%	$23.49	$0.26	-4.17%	-$0.01

Table 3. Regression Results: Log of Percentage Effective Spread (NBBO)

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of percentage effective spread based on national best bid and offer. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Average percentage quoted spread" and "average quote midpoint" are the average of percentage quoted spread and quote midpoint for each specialist firm. "Average dollar spread" is calculated by multiplying "average percentage quoted spread" and "average quote midpoint". "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 x e^b$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in $" is calculated by multiplying "average dollar spread" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log(Number of Trades)	Log (Trade Size)	Log(Market Capitalization)	Volatility	Log(Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-2.448 ***	-0.182 ***	-0.019 ***	-0.072 ***	0.279 ***	-0.418 ***	0.138 ***	-0.074 ***	0.197 ***	0.7832	0.8106	16.23	0.000	99.46%
2	-2.589 ***	-0.193 ***	0.036 ***	-0.093 ***	0.224 ***	-0.413 ***	0.148 ***	-0.144 ***	0.025	0.6887	0.7105	10.06	0.000	92.27%
3	-1.744 ***	-0.200 ***	-0.016	-0.134 ***	0.180 ***	-0.356 ***	0.300 ***	-0.324 ***	0.009	0.7796	0.7999	7.78	0.000	81.12%
4	-2.600 ***	-0.215 ***	-0.011	-0.075 ***	0.327 ***	-0.382 ***	0.104 ***	-0.061 ***	0.040	0.7968	0.8194	17.66	0.000	85.30%
5	-1.850 ***	-0.192 ***	-0.018 *	-0.124 ***	0.320 ***	-0.419 ***	-0.132 ***	-0.209 ***	0.064 ***	0.8031	0.8177	8.60	0.000	77.30%
6	-2.949 ***	-0.243 ***	-0.023	-0.029 **	0.377 ***	-0.464 ***	0.076	-0.042	0.206 ***	0.8267	0.8377	6.55	0.000	55.24%
7	-3.142 ***	-0.148 ***	0.023	-0.106 ***	0.311 ***	-0.375 ***	0.441 ***	-0.224 ***	-0.256 ***	0.4111	0.4174	2.12	0.009	86.81%
8	-2.325 ***	-0.225 ***	-0.085 ***	-0.043 ***	0.395 ***	-0.475 ***	-0.231 ***	-0.137 ***	-0.041	0.7166	0.7272	5.54	0.000	81.82%
9	-2.173 ***	-0.267 ***	-0.018	-0.120 ***	0.325 ***	-0.222 ***	0.227 **	-0.363 ***	0.003	0.8165	0.8240	5.29	0.000	53.33%
10	-0.967 ***	-0.191 ***	-0.046 ***	-0.190 ***	0.291 ***	-0.289 ***	0.023	-0.096 ***	0.108 **	0.7750	0.7877	7.20	0.000	97.78%
11	-2.457 ***	-0.201 ***	0.063 **	-0.214 ***	0.376 ***	-0.110 **	0.280 *	-0.271 ***		0.6542	0.6683	2.47	0.012	89.29%
12	-2.215 ***	-0.130 ***	0.079 ***	-0.216 ***	0.248 ***	-0.230 ***	-0.160 *	-0.068 **	0.310 ***	0.8384	0.8461	10.22	0.000	60.00%
13	-2.146 ***	-0.170 ***	-0.006	-0.101 ***	0.255 ***	-0.499 ***	-0.176 *	-0.170 ***	0.088 *	0.7572	0.7691	14.93	0.000	86.67%
14	-1.578 ***	-0.147 ***	0.068 **	-0.202 ***	0.113 ***	-0.365 ***	0.198	-0.292 ***	-0.051	0.8224	0.8219	0.79	0.529	0.00%
15	-2.616 ***	-0.231 ***	0.071 ***	-0.106 ***	0.278 ***	-0.384 ***	-0.161 **	-0.155 ***	0.013	0.7844	0.7912	12.46	0.000	100.00%
16	-1.968 ***	-0.140 ***	-0.020	-0.130 ***	0.352 ***	-0.430 ***	-0.208 **	-0.163 ***	0.044	0.8261	0.8309	7.69	0.000	83.33%
17	-1.428 *	-0.029	0.086	-0.299 ***	0.110 ***	-0.288 ***	0.121	-0.362 ***	0.174	0.3263	0.3379	4.68	0.003	100.00%
18	-2.108 ***	-0.203 ***	-0.075 *	-0.088 **	0.453 ***	-0.447 ***	-0.408 *	-0.229 ***	0.239 **	0.7832	0.7856	3.51	0.062	na
19	-0.989 **	-0.215 ***	-0.078 **	-0.112 ***	0.245 ***	-0.546 ***	-0.756 ***	-0.570 ***		0.7791	0.7970	47.46	0.000	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates						
Specialist Firm No	**Mean**	**Median**	**Std**	**Min**	**Max**	**Av. % Effective Spread (NBBO)**	**Av. Quote Midpoint**	**Av. Dollar Spread**	**Mean Deviation in %**	**Mean Deviation in $**	**Total Daily Deviation in $**	**Total Estimated Deviation for March 2001**
1	-0.388	-0.383	0.163	-0.797	0.134	0.57%	$34.99	$0.20	-32.15%	-$0.06	-$31,751.68	-$666,785.37
2	-0.145	-0.171	0.177	-0.473	0.305	0.61%	$26.11	$0.16	-13.48%	-$0.02	-$8,815.38	-$185,122.88
3	-0.085	-0.102	0.196	-0.430	0.554	0.75%	$26.37	$0.20	-8.12%	-$0.02	-$6,691.58	-$140,523.12
4	-0.115	-0.129	0.149	-0.530	0.294	0.68%	$25.89	$0.18	-10.84%	-$0.02	-$7,875.08	-$165,376.60
5	0.016	-0.036	0.204	-0.250	0.544	0.81%	$22.23	$0.18	1.64%	$0.00	$1,109.65	$23,302.63
6	-0.076	-0.057	0.109	-0.276	0.059	0.62%	$27.20	$0.17	-7.36%	-$0.01	-$3,140.19	-$65,944.05
7	0.274	0.275	0.125	0.029	0.456	0.72%	$22.87	$0.17	31.48%	$0.05	$24,188.62	$507,960.96
8	0.063	0.090	0.121	-0.147	0.225	0.88%	$22.76	$0.20	6.46%	$0.01	$2,613.92	$54,892.26
9	0.071	-0.013	0.198	-0.195	0.472	0.74%	$25.88	$0.19	7.34%	$0.01	$5,107.97	$107,267.38
10	-0.288	-0.284	0.113	-0.444	-0.038	1.08%	$19.05	$0.21	-24.99%	-$0.05	-$4,076.43	-$85,605.07
11	0.252	0.219	0.170	0.085	0.618	0.68%	$23.30	$0.16	28.72%	$0.05	$11,885.05	$249,586.14
12	0.010	0.051	0.110	-0.173	0.151	0.73%	$23.64	$0.17	0.96%	$0.00	$370.81	$7,787.07
13	-0.028	-0.065	0.141	-0.208	0.170	0.77%	$20.17	$0.15	-2.75%	$0.00	-$1,139.64	-$23,932.53
14	-0.113	-0.124	0.077	-0.192	0.011	0.85%	$20.45	$0.17	-10.68%	-$0.02	-$4,398.64	-$92,371.37
15	-0.084	-0.100	0.096	-0.190	0.064	0.81%	$19.54	$0.16	-8.07%	-$0.01	-$2,394.92	-$50,293.23
16	-0.051	-0.054	0.077	-0.150	0.039	0.76%	$23.09	$0.18	-4.94%	-$0.01	-$1,494.06	-$31,375.22
17	0.150	0.197	0.191	-0.118	0.325	0.89%	$19.28	$0.17	16.22%	$0.03	$2,493.96	$52,373.17
18	0.103	0.103	0.104	0.029	0.176	0.79%	$21.81	$0.17	10.80%	$0.02	$3,572.62	$75,024.92
19	-0.389	-0.389	na	-0.389	-0.389	0.97%	$21.71	$0.21	-32.20%	-$0.07	-$5,219.43	-$109,608.10
Average	-0.116	-0.124	0.234	-0.797	0.618	0.78%	$23.49	$0.18	-2.73%	-$0.01	-$1,350.23	-$28,354.89

Table 4. Regression Results: Log of Percentage Effective Spread (NYSE)

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of percentage effective spread based on NYSE quotes. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Average percentage quoted spread" and "average quote midpoint" are the average of percentage quoted spread and quote midpoint for each specialist firm. "Average dollar spread" is calculated by multiplying "average percentage quoted spread" and "average quote midpoint". "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 x e^b$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in $" is calculated by multiplying "average dollar spread" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-2.372 ***	-0.178 ***	-0.026 ***	-0.075 ***	0.272 ***	-0.427 ***	0.172 ***	-0.078 ***	0.204 ***	0.7884	0.8162	17.05	0.000	98.96%
2	-2.337 ***	-0.193 ***	0.014 *	-0.094 ***	0.219 ***	-0.439 ***	0.181 ***	-0.177 ***	0.028	0.8042	0.8289	18.36	0.000	95.86%
3	-1.640 ***	-0.195 ***	-0.028 **	-0.132 ***	0.177 ***	-0.381 ***	0.369 ***	-0.337 ***	0.009	0.7867	0.8049	7.21	0.000	83.40%
4	-2.393 ***	-0.211 ***	-0.024 ***	-0.078 ***	0.313 ***	-0.407 ***	0.186 ***	-0.080 ***	0.028	0.8047	0.8273	18.42	0.000	89.53%
5	-1.726 ***	-0.189 ***	-0.024 ***	-0.127 ***	0.311 ***	-0.432 ***	-0.046	-0.235 ***	0.081 ***	0.8132	0.8269	8.35	0.000	76.87%
6	-2.827 ***	-0.240 ***	-0.027 *	-0.033 **	0.359 ***	-0.477 ***	0.096	-0.068 **	0.205 ***	0.8322	0.8439	7.14	0.000	56.19%
7	-3.052 ***	-0.150 ***	0.021	-0.106 ***	0.302 ***	-0.393 ***	0.464 ***	-0.258 ***	-0.287 ***	0.4209	0.4272	2.17	0.007	85.71%
8	-2.282 ***	-0.221 ***	-0.084 ***	-0.043 ***	0.390 ***	-0.495 ***	-0.237 ***	-0.162 ***	-0.029	0.7309	0.7431	6.47	0.000	89.09%
9	-2.282 ***	-0.268 ***	-0.013	-0.113 ***	0.312 ***	-0.224 ***	0.141	-0.383 ***	-0.009	0.8222	0.8302	5.71	0.000	48.89%
10	-0.829 ***	-0.184 ***	-0.060 ***	-0.191 ***	0.287 ***	-0.312 ***	0.037	-0.105 ***	0.101 **	0.7779	0.7912	8.31	0.000	100.00%
11	-2.373 ***	-0.190 ***	0.065 **	-0.226 ***	0.357 ***	-0.118 ***	0.499 ***	-0.272 ***		0.6586	0.6739	2.38	0.016	89.29%
12	-2.234 ***	-0.128 ***	0.072 ***	-0.208 ***	0.242 ***	-0.250 ***	-0.078	-0.098 ***	0.285 ***	0.8469	0.8549	11.09	0.000	66.67%
13	-1.961 ***	-0.160 ***	-0.020	-0.108 ***	0.247 ***	-0.514 ***	-0.096	-0.165 ***	0.097 **	0.7674	0.7784	14.33	0.000	100.00%
14	-1.537 ***	-0.150 ***	0.063 *	-0.202 ***	0.112 ***	-0.365 ***	0.202	-0.298 ***	-0.056	0.8211	0.8203	0.69	0.601	0.00%
15	-2.476 ***	-0.230 ***	0.058 ***	-0.108 ***	0.282 ***	-0.398 ***	-0.072	-0.154 ***	0.010	0.7928	0.8001	13.67	0.000	100.00%
16	-1.782 ***	-0.127 ***	-0.034 **	-0.135 ***	0.345 ***	-0.460 ***	-0.094	-0.155 ***	0.068	0.8325	0.8362	6.15	0.000	83.33%
17	-1.426 *	-0.031	0.086	-0.296 ***	0.108 ***	-0.290 ***	0.157	-0.380 ***	0.154	0.3297	0.3393	4.22	0.006	100.00%
18	-2.036 ***	-0.198 ***	-0.061	-0.096 **	0.437 ***	-0.463 ***	-0.500 **	-0.241 ***	0.225 **	0.7892	0.7898	2.04	0.154	na
19	-0.866 **	-0.226 ***	-0.096 ***	-0.113 ***	0.272 ***	-0.536 ***	-0.548 ***	-0.649 ***		0.8025	0.8204	53.57	0.000	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates				
Specialist Firm No	**Mean**	**Median**	**Std**	**Min**	**Max**	**Av. % Effective Spread (NYSE)**	**Av. Quote Midpoint**	**Av. Dollar Spread**	**Mean Deviation in %**	**Mean Deviation in $**
1	-0.361	-0.354	0.164	-0.768	0.122	0.57%	$34.99	$0.20	-30.29%	-$0.06
2	-0.141	-0.170	0.176	-0.472	0.306	0.62%	$26.11	$0.16	-13.13%	-$0.02
3	-0.097	-0.118	0.176	-0.432	0.468	0.77%	$26.37	$0.20	-9.23%	-$0.02
4	-0.133	-0.148	0.151	-0.529	0.290	0.69%	$25.89	$0.18	-12.47%	-$0.02
5	-0.004	-0.044	0.189	-0.275	0.498	0.83%	$22.23	$0.18	-0.41%	$0.00
6	-0.071	-0.043	0.113	-0.276	0.072	0.62%	$27.20	$0.17	-6.85%	-$0.01
7	0.268	0.282	0.128	0.028	0.447	0.73%	$22.87	$0.17	30.74%	$0.05
8	0.070	0.095	0.125	-0.136	0.230	0.88%	$22.76	$0.20	7.26%	$0.01
9	0.077	-0.001	0.192	-0.180	0.439	0.71%	$25.88	$0.18	8.03%	$0.01
10	-0.281	-0.276	0.119	-0.440	-0.020	1.10%	$19.05	$0.21	-24.52%	-$0.05
11	0.275	0.245	0.172	0.122	0.650	0.68%	$23.30	$0.16	31.70%	$0.05
12	0.012	0.058	0.108	-0.156	0.148	0.73%	$23.64	$0.17	1.17%	$0.00
13	-0.035	-0.068	0.138	-0.200	0.166	0.78%	$20.17	$0.16	-3.45%	-$0.01
14	-0.172	-0.162	0.071	-0.282	-0.105	0.85%	$20.45	$0.17	-15.79%	-$0.03
15	-0.088	-0.124	0.100	-0.187	0.070	0.83%	$19.54	$0.16	-8.46%	-$0.01
16	-0.049	-0.050	0.071	-0.146	0.020	0.77%	$23.09	$0.18	-4.75%	-$0.01
17	0.126	0.181	0.184	-0.137	0.280	0.90%	$19.28	$0.17	13.46%	$0.02
18	0.074	0.074	0.079	0.018	0.130	0.80%	$21.81	$0.17	7.67%	$0.01
19	-0.395	-0.395	na	-0.395	-0.395	0.99%	$21.71	$0.21	-32.66%	-$0.07
Average	-0.117	-0.135	0.224	-0.768	0.650	0.78%	$23.49	$0.18	-3.26%	-$0.01

Table 5. Regression Results: Log of Total Quoted Share Depth

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of total quoted share depth. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 x e^b$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in shares" is calculated by multiplying "average total quoted share" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-0.087	0.097 ***	0.470 ***	0.091 ***	-0.138 ***	-0.434 ***	0.069	0.316 ***	0.007	0.5307	0.5666	10.01	0.000	45.38%
2	-0.193 **	0.093 ***	0.487 ***	0.054 ***	-0.092 ***	-0.339 ***	0.123 ***	0.210 ***	0.118 ***	0.4565	0.5166	16.05	0.000	86.36%
3	-0.048	0.098 ***	0.513 ***	0.056 ***	-0.082 ***	-0.352 ***	0.117 *	0.332 ***	0.065	0.5640	0.5870	4.82	0.000	61.77%
4	-0.049	0.134 ***	0.471 ***	0.062 ***	-0.183 ***	-0.460 ***	-0.005	0.281 ***	-0.114 ***	0.5081	0.5568	15.37	0.000	94.82%
5	0.291 **	0.052 ***	0.436 ***	0.084 ***	-0.138 ***	-0.371 ***	0.034	0.152 ***	0.096 ***	0.4542	0.4714	4.20	0.000	47.53%
6	0.212	0.133 ***	0.546 ***	0.033	-0.247 ***	-0.425 ***	0.105	0.056	0.115	0.5218	0.5482	5.77	0.000	57.14%
7	0.616 ***	0.102 ***	0.403 ***	0.080 ***	-0.188 ***	-0.483 ***	-0.037	0.420 ***	0.717 ***	0.5130	0.5371	10.65	0.000	76.92%
8	0.794 ***	0.058 ***	0.494 ***	0.072 ***	-0.213 ***	-0.437 ***	-0.107	0.168 ***	-0.263 ***	0.6056	0.6618	18.56	0.000	100.00%
9	1.224 ***	0.015	0.309 ***	0.082 ***	-0.068 **	-0.310 ***	0.099	0.093 *	0.063	0.3212	0.3395	3.72	0.000	57.78%
10	0.251	0.113 ***	0.418 ***	0.096 ***	-0.153 ***	-0.536 ***	-0.098	0.309 ***	-0.060	0.5913	0.6187	15.54	0.000	86.67%
11	-0.310	0.074 **	0.478 ***	0.128 ***	-0.151 ***	-0.479 ***	-0.664 ***	0.310 ***		0.5260	0.5401	3.21	0.001	35.71%
12	0.151	0.060 ***	0.389 ***	0.106 ***	-0.072 ***	-0.385 ***	0.261 **	0.031	0.119	0.5070	0.5319	9.69	0.000	93.33%
13	0.502 *	0.124 ***	0.433 ***	0.061 **	-0.129 ***	-0.429 ***	0.031	0.504 ***	0.102	0.4330	0.4668	15.72	0.000	100.00%
14	-0.291	0.094 **	0.418 ***	0.161 ***	-0.069 ***	-0.552 ***	0.270	0.292 ***	0.088	0.5794	0.5783	0.87	0.484	0.00%
15	0.561 **	0.120 ***	0.405 ***	0.090 ***	-0.172 ***	-0.510 ***	-0.002	0.371 ***	0.376 ***	0.3547	0.3808	18.81	0.000	83.33%
16	-0.143	0.056 **	0.310 ***	0.237 ***	-0.154 ***	-0.627 ***	-0.093	0.311 ***	-0.110 *	0.4373	0.4549	6.34	0.000	100.00%
17	0.270	0.029	0.433 ***	0.123 ***	-0.061 ***	-0.447 ***	0.007	0.173 ***	-0.324 ***	0.5327	0.5563	3.06	0.028	100.00%
18	-1.141 *	0.024	0.534 ***	0.159 ***	-0.239 ***	-0.395 ***	0.833 **	0.231 **	-0.203	0.5286	0.5273	0.52	0.471	na
19	-1.781 ***	0.210 ***	0.487 ***	0.266 ***	-0.294 ***	-0.853 ***	0.238	1.035 ***		0.5844	0.5892	7.14	0.008	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates		
Specialist Firm No	**Mean**	**Median**	**Std**	**Min**	**Max**	**Average Total Quoted Share Depth**	**Mean Deviation in %**	**Mean Deviation in Shares**
1	-0.002	-0.026	0.185	-0.386	0.465	5,492.00	-0.18%	-10.14
2	0.203	0.158	0.224	-0.150	1.139	4,623.27	22.52%	1,041.08
3	-0.071	-0.074	0.161	-0.382	0.565	4,860.18	-6.90%	-335.36
4	0.290	0.267	0.181	0.010	0.763	4,635.63	33.60%	1,557.45
5	-0.010	-0.030	0.138	-0.319	0.242	4,629.23	-1.00%	-46.34
6	-0.075	-0.060	0.176	-0.401	0.294	4,230.79	-7.19%	-304.23
7	0.003	-0.024	0.149	-0.173	0.289	4,835.98	0.29%	14.02
8	-0.332	-0.284	0.233	-0.795	0.105	5,408.40	-28.28%	-1,529.35
9	-0.043	-0.041	0.134	-0.272	0.210	4,366.73	-4.20%	-183.39
10	0.136	0.163	0.191	-0.169	0.522	4,630.32	14.56%	673.96
11	-0.094	-0.077	0.147	-0.329	0.066	3,601.83	-8.96%	-322.89
12	0.148	0.158	0.144	-0.059	0.358	4,361.82	15.93%	694.90
13	-0.192	-0.255	0.184	-0.320	0.211	5,586.19	-17.49%	-977.26
14	-0.208	-0.227	0.098	-0.333	-0.103	3,704.50	-18.81%	-696.87
15	-0.019	-0.070	0.189	-0.170	0.305	5,410.25	-1.88%	-101.60
16	-0.170	-0.182	0.114	-0.274	0.014	4,382.10	-15.63%	-684.95
17	-0.271	-0.278	0.061	-0.338	-0.190	5,865.12	-23.75%	-1,393.05
18	-0.101	-0.101	0.060	-0.143	-0.059	4,145.69	-9.59%	-397.71
19	0.219	0.219	na	0.219	0.219	5,712.60	24.46%	1,397.54
Average	0.043	0.027	0.234	-0.795	1.139	4,762.24	-1.71%	-84.43

Table 6. Regression Results: Log of Total Quoted Dollar Depth

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of total quoted dollar depth. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Average percentage quoted spread" and "average quote midpoint" are the average of percentage quoted spread and quote midpoint for each specialist firm. "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 xeb$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation in $" is calculated by multiplying "average total quoted dollar depth" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-0.087	0.097 ***	0.470 ***	0.091 ***	-0.138 ***	0.566 ***	0.068	0.316 ***	0.007	0.6925	0.7160	10.01	0.000	45.32%
2	-0.189 **	0.094 ***	0.487 ***	0.053 ***	-0.093 ***	0.662 ***	0.124 ***	0.210 ***	0.117 ***	0.7015	0.7345	16.06	0.000	86.24%
3	-0.051	0.099 ***	0.514 ***	0.055 ***	-0.083 ***	0.649 ***	0.117 *	0.331 ***	0.065 *	0.7285	0.7427	4.80	0.000	61.26%
4	-0.049	0.134 ***	0.471 ***	0.062 ***	-0.184 ***	0.541 ***	-0.006	0.281 ***	-0.114 ***	0.6925	0.7229	15.33	0.000	94.82%
5	0.287 **	0.052 ***	0.436 ***	0.084 ***	-0.138 ***	0.630 ***	0.033	0.153 ***	0.097 ***	0.6997	0.7092	4.20	0.000	47.96%
6	0.213	0.134 ***	0.546 ***	0.032	-0.248 ***	0.576 ***	0.106	0.056	0.115	0.6930	0.7100	5.76	0.000	57.14%
7	0.617 ***	0.102 ***	0.403 ***	0.080 ***	-0.188 ***	0.517 ***	-0.036	0.420 ***	0.718 ***	0.6986	0.7135	10.64	0.000	76.92%
8	0.796 ***	0.058 ***	0.494 ***	0.072 ***	-0.214 ***	0.562 ***	-0.106	0.167 ***	-0.263 ***	0.6299	0.6827	18.60	0.000	100.00%
9	1.230 ***	0.016	0.308 ***	0.081 ***	-0.069 **	0.690 ***	0.097	0.094 *	0.063	0.6888	0.6973	3.74	0.000	57.78%
10	0.250	0.113 ***	0.417 ***	0.097 ***	-0.154 ***	0.463 ***	-0.100	0.309 ***	-0.060	0.6405	0.6646	15.54	0.000	86.67%
11	-0.318	0.074 **	0.478 ***	0.128 ***	-0.151 ***	0.524 ***	-0.662 ***	0.310 ***		0.6636	0.6736	3.21	0.001	35.71%
12	0.147	0.060 ***	0.389 ***	0.106 ***	-0.071 ***	0.614 ***	0.260 **	0.031	0.117	0.7659	0.7777	9.65	0.000	93.33%
13	0.511 *	0.124 ***	0.432 ***	0.061 **	-0.129 ***	0.571 ***	0.031	0.503 ***	0.104	0.6120	0.6352	15.78	0.000	100.00%
14	-0.286	0.094 **	0.417 ***	0.162 ***	-0.070 ***	0.448 ***	0.268	0.291 ***	0.086	0.6365	0.6356	0.86	0.487	0.00%
15	0.562 **	0.121 ***	0.405 ***	0.089 ***	-0.174 ***	0.491 ***	-0.001	0.373 ***	0.378 ***	0.5944	0.6109	18.95	0.000	83.33%
16	-0.148	0.056 **	0.311 ***	0.237 ***	-0.155 ***	0.373 ***	-0.092	0.312 ***	-0.109 *	0.6644	0.6750	6.33	0.000	100.00%
17	0.280	0.030	0.432 ***	0.123 ***	-0.062 ***	0.552 ***	0.008	0.174 ***	-0.324 ***	0.6997	0.7148	3.05	0.028	100.00%
18	-1.138 *	0.023	0.533 ***	0.160 ***	-0.238 ***	0.603 ***	0.832 **	0.231 **	-0.203	0.6053	0.6042	0.54	0.462	na
19	-1.794 ***	0.210 ***	0.488 ***	0.266 ***	-0.294 ***	0.150 **	0.241	1.037 ***		0.6473	0.6514	7.20	0.008	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates		
Specialist Firm No	**Mean**	**Median**	**Std**	**Min**	**Max**	**Average Total Quoted Dollar Depth**	**Mean Deviation in %**	**Mean Deviation in $**
1	-0.002	-0.027	0.185	-0.388	0.465	$110,198.58	-0.24%	-$266.50
2	0.202	0.157	0.224	-0.151	1.139	$105,227.43	22.42%	$23,594.37
3	-0.072	-0.074	0.161	-0.382	0.565	$106,680.16	-6.91%	-$7,370.11
4	0.290	0.268	0.180	0.011	0.760	$96,041.93	33.62%	$32,287.88
5	-0.009	-0.029	0.138	-0.317	0.243	$84,473.88	-0.88%	-$743.38
6	-0.074	-0.059	0.176	-0.401	0.294	$97,084.20	-7.17%	-$6,958.69
7	0.002	-0.025	0.149	-0.174	0.287	$87,305.43	0.20%	$171.10
8	-0.332	-0.284	0.234	-0.796	0.107	$85,454.28	-28.27%	-$24,160.74
9	-0.042	-0.040	0.134	-0.272	0.211	$96,313.50	-4.14%	-$3,989.88
10	0.135	0.166	0.191	-0.169	0.521	$60,833.35	14.47%	$8,800.43
11	-0.093	-0.076	0.147	-0.329	0.066	$77,673.34	-8.92%	-$6,932.19
12	0.147	0.159	0.144	-0.060	0.357	$89,024.96	15.89%	$14,142.87
13	-0.192	-0.255	0.184	-0.319	0.212	$91,496.02	-17.44%	-$15,955.71
14	-0.209	-0.227	0.098	-0.334	-0.103	$59,853.57	-18.83%	-$11,270.48
15	-0.021	-0.071	0.189	-0.173	0.304	$86,048.74	-2.04%	-$1,753.84
16	-0.170	-0.182	0.114	-0.274	0.014	$85,567.29	-15.67%	-$13,407.46
17	-0.270	-0.277	0.061	-0.337	-0.190	$98,624.85	-23.69%	-$23,361.36
18	-0.102	-0.102	0.061	-0.144	-0.059	$71,770.09	-9.65%	-$6,927.81
19	0.219	0.219	na	0.219	0.219	$81,369.85	24.54%	$19,971.76
Average	0.043	0.027	0.234	-0.796	1.139	$87,949.55	-1.72%	-$1,269.99

Table 7. Regression Results: Log of Price Improvement

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of price improvement. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Pairwise rejection rate is the percentage of all pairwise comparisons of specialist dummy coefficients that are significantly different from each other at the 10% level for each firm. The first part of Panel B reports the distribution of the estimated specialist dummy coefficients. Second part of Panel B reports the economic significance of the specialist dummies. "Mean deviation in %" is calculated as follows: If b is the value of the estimated coefficient of a specialist dummy, then the predicted change in the dependent variable with respect to the excluded specialist is given by $\log(Y_2)-\log(Y_1)=b$, where $\log(Y_i)$, i=1,2 is the predicted value of the dependent variable for the excluded and included specialists, respectively. Then, $Y_2=Y_1 x e^b$ and "mean deviation in %" is given by $(Y_2-Y_1)/Y_1=e^b-1$, where b is the mean value of all estimated specialist dummy variables for a given firm. "Mean deviation from average price improvement" is calculated by multiplying "average price improvement" by "mean deviation in %".

Panel A: Coefficient Estimates and Test Results

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-Value	Pairwise Rejection Rate
1	-0.721 ***	-0.045 ***	-0.081 ***	0.046 ***	-0.002	0.034 ***	-0.429 ***	-0.193 ***	-0.067 ***	0.1299	0.2119	11.93	0.000	73.83%
2	-0.522 ***	-0.054 ***	-0.082 ***	0.013 **	0.037 ***	0.099 ***	-0.472 ***	-0.242 ***	-0.143 ***	0.1522	0.2280	12.62	0.000	63.74%
3	-0.780 ***	-0.048 ***	-0.051 ***	0.009	0.028 ***	0.115 ***	-0.456 ***	-0.207 ***	-0.067 **	0.1407	0.2341	9.18	0.000	72.12%
4	-0.846 ***	-0.070 ***	-0.083 ***	0.033 ***	0.049 ***	0.114 ***	-0.257 ***	-0.169 ***	-0.082 ***	0.1158	0.1838	11.73	0.000	74.09%
5	-0.542 ***	-0.076 ***	-0.083 ***	0.035 ***	0.039 ***	0.061 ***	-0.591 ***	-0.225 ***	-0.093 ***	0.1325	0.1849	6.83	0.000	67.86%
6	-0.779 ***	-0.034 **	-0.064 ***	0.003	0.030	0.097 ***	-0.312 ***	-0.025	0.027	0.0840	0.1213	4.42	0.000	43.81%
7	-0.903 ***	-0.078 ***	-0.062 ***	0.043 ***	0.058 ***	0.072 ***	-0.511 ***	-0.266 ***	-0.167 ***	0.1332	0.1870	12.78	0.000	81.32%
8	-1.168 ***	-0.135 ***	-0.085 ***	0.070 ***	0.105 ***	0.146 ***	-0.790 ***	-0.179 ***	-0.004	0.2676	0.2930	5.00	0.000	54.55%
9	-1.391 ***	-0.136 ***	-0.074 ***	0.097 ***	0.061 **	0.043	-0.319 ***	-0.343 ***	-0.330 ***	0.1503	0.1521	1.14	0.325	40.00%
10	-0.618 ***	-0.122 ***	-0.116 ***	0.044 **	0.083 ***	0.143 ***	-0.368 ***	-0.279 ***	-0.144 **	0.2514	0.2867	10.38	0.000	82.22%
11	-0.836 ***	-0.066 ***	-0.031	0.023	0.040	0.056	-0.802 ***	-0.073		0.1375	0.1506	2.15	0.030	21.43%
12	-1.512 ***	-0.078 ***	-0.001	0.033	0.041 **	0.128 ***	-0.254 **	-0.229 ***	-0.174 **	0.1270	0.2428	26.71	0.000	80.00%
13	-0.392 *	-0.107 ***	-0.157 ***	0.023	0.063 ***	0.211 ***	-0.193 *	-0.375 ***	0.073	0.2500	0.2806	11.58	0.000	93.33%
14	0.421	0.001	-0.197 ***	-0.028	0.019	0.078	-0.153	-0.212 ***	0.036	0.1947	0.1842	0.34	0.851	0.00%
15	-1.217 ***	-0.137 ***	-0.029	0.022	0.110 ***	0.245 ***	-0.579 ***	-0.189 ***	-0.061	0.2098	0.2499	21.85	0.000	83.33%
16	0.131	0.042 **	-0.048 **	-0.105 ***	0.042 *	0.236 ***	-0.438 ***	-0.335 ***	-0.187 ***	0.1734	0.1961	5.79	0.000	83.33%
17	-0.469	-0.063 **	-0.125 ***	0.028	0.017	0.016	-0.346 ***	-0.359 ***	-0.404 ***	0.2149	0.2390	3.38	0.018	100.00%
18	0.252	0.041	-0.110 **	-0.042	0.040	-0.051	-0.256	-0.082	0.001	0.0597	0.0685	2.09	0.149	na
19	0.651 *	-0.178 ***	-0.276 ***	0.029	0.133 ***	0.232 ***	-0.391 **	-0.344 ***		0.3489	0.3665	14.59	0.000	na

Panel B.

	Distribution of the Estimated Specialist Dummy Coefficients					Economic Significance of the Estimates		
Specialist Firm No	Mean	Median	Std	Min	Max	Average Price Improvement	Mean Deviation in %	Mean Deviation from Average Price Improvement
1	-0.162	-0.133	0.146	-0.601	0.167	38.01%	-14.92%	-5.67%
2	-0.067	-0.041	0.129	-0.478	0.155	38.24%	-6.49%	-2.48%
3	-0.035	-0.049	0.153	-0.435	0.305	39.88%	-3.43%	-1.37%
4	-0.089	-0.083	0.121	-0.409	0.167	37.86%	-8.52%	-3.23%
5	-0.034	-0.021	0.149	-0.325	0.288	40.15%	-3.32%	-1.33%
6	0.017	0.027	0.105	-0.226	0.206	37.85%	1.70%	0.64%
7	-0.040	-0.009	0.112	-0.287	0.105	38.44%	-3.89%	-1.49%
8	-0.076	-0.086	0.112	-0.209	0.203	34.05%	-7.36%	-2.50%
9	0.071	0.041	0.067	-0.013	0.170	35.60%	7.37%	2.62%
10	-0.066	-0.099	0.164	-0.336	0.200	37.49%	-6.36%	-2.39%
11	0.050	0.030	0.086	-0.060	0.199	42.19%	5.09%	2.15%
12	0.028	0.033	0.210	-0.362	0.323	39.09%	2.79%	1.09%
13	-0.035	-0.021	0.136	-0.261	0.131	36.27%	-3.39%	-1.23%
14	0.106	0.096	0.040	0.074	0.176	37.54%	11.24%	4.22%
15	0.059	0.036	0.148	-0.145	0.262	39.80%	6.12%	2.43%
16	-0.135	-0.182	0.114	-0.267	-0.010	34.74%	-12.65%	-4.39%
17	0.225	0.226	0.082	0.123	0.323	32.98%	25.19%	8.31%
18	0.065	0.065	0.085	0.005	0.125	38.30%	6.74%	2.58%
19	-0.198	-0.198	na	-0.198	-0.198	46.77%	-17.93%	-8.38%
Average	-0.062	-0.053	0.149	-0.601	0.323	38.17%	-1.16%	-0.55%

Table 8. Pooled Regression Results

This Table reports the coefficient estimates and associated p-values for the specialist firm dummies and adjusted R^2 for both the base model, where individual specialist dummies are excluded, and the full model, where individual specialist dummies are included. In addition, F-stats and the associated p-values are reported for the null hypothesis that specialist firm dummies are equal. Specialist Firm 7 is the excluded firm.

	Log of % Quoted Spread				Log of % Effective Spread (NBBO)				Log of % Effective Spread (NYSE)			
	Base Model		Full Model		Base Model		Full Model		Base Model		Full Model	
Specialist Firm No	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
1	-0.152	0.000	0.374	0.000	-0.113	0.000	0.648	0.000	-0.114	0.000	0.622	0.000
2	-0.019	0.030	0.324	0.000	-0.033	0.003	0.407	0.000	-0.025	0.020	0.416	0.000
3	0.045	0.000	0.271	0.000	0.025	0.044	0.430	0.000	0.029	0.013	0.435	0.000
4	-0.009	0.343	0.305	0.000	0.016	0.154	0.426	0.000	0.023	0.031	0.442	0.000
5	0.041	0.000	0.252	0.000	0.075	0.000	0.426	0.000	0.076	0.000	0.437	0.000
6	-0.080	0.000	0.107	0.111	-0.089	0.000	0.121	0.162	-0.080	0.000	0.137	0.094
8	0.031	0.020	0.175	0.000	0.051	0.002	0.273	0.000	0.052	0.001	0.275	0.000
9	0.104	0.000	0.147	0.000	0.129	0.000	0.397	0.000	0.115	0.000	0.361	0.000
10	0.109	0.000	0.469	0.000	0.126	0.000	0.634	0.000	0.133	0.000	0.630	0.000
11	-0.017	0.366	-0.075	0.150	-0.009	0.696	0.121	0.073	0.004	0.840	0.125	0.050
12	0.001	0.938	0.158	0.001	-0.038	0.035	0.276	0.000	-0.037	0.030	0.276	0.000
13	-0.058	0.000	0.184	0.000	-0.028	0.082	0.310	0.000	-0.024	0.111	0.312	0.000
14	-0.042	0.095	0.103	0.480	-0.021	0.498	0.418	0.026	-0.028	0.359	0.405	0.023
15	0.073	0.000	0.309	0.000	0.025	0.118	0.389	0.000	0.038	0.011	0.404	0.000
16	0.071	0.000	0.290	0.000	0.060	0.001	0.384	0.000	0.072	0.000	0.396	0.000
17	-0.081	0.000	-0.109	0.016	-0.052	0.009	0.131	0.024	-0.054	0.005	0.148	0.008
18	-0.079	0.002	0.100	0.067	-0.062	0.056	0.253	0.000	-0.064	0.040	0.253	0.000
19	-0.016	0.404	0.152	0.000	-0.049	0.038	0.283	0.000	-0.045	0.049	0.287	0.000
Adj. R^2	81.69%		83.69%		72.38%		74.00%		74.93%		76.57%	

H_0: $D_2=D_3=\ldots=D_{19}=0$

F-Stat	96.2510	20.2706	49.1576	13.7579	55.7823	15.0588
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 8. cont'd

	Log of Total Quoted Share Depth				Log of Total Quoted Dollar Depth				Log of Price Improvement			
	Base Model		Full Model		Base Model		Full Model		Base Model		Full Model	
Specialist Firm No	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
1	0.029	0.021	0.024	0.798	0.029	0.022	0.023	0.802	-0.030	0.003	0.121	0.098
2	0.017	0.169	-0.213	0.000	0.017	0.177	-0.213	0.000	-0.023	0.020	0.023	0.613
3	0.133	0.000	0.135	0.025	0.133	0.000	0.134	0.026	-0.012	0.270	-0.018	0.719
4	-0.010	0.420	-0.326	0.000	-0.010	0.406	-0.327	0.000	-0.052	0.000	-0.016	0.771
5	0.038	0.005	-0.012	0.807	0.038	0.005	-0.014	0.774	0.055	0.000	0.071	0.077
6	0.063	0.001	0.224	0.018	0.063	0.001	0.222	0.019	-0.066	0.000	-0.114	0.126
8	0.167	0.000	0.434	0.000	0.167	0.000	0.433	0.000	-0.120	0.000	-0.037	0.510
9	0.105	0.000	0.091	0.091	0.105	0.000	0.090	0.096	-0.086	0.000	-0.173	0.000
10	-0.030	0.071	-0.250	0.000	-0.030	0.069	-0.250	0.000	-0.060	0.000	0.028	0.571
11	-0.030	0.239	-0.079	0.283	-0.031	0.232	-0.081	0.273	0.058	0.004	0.036	0.548
12	0.051	0.011	-0.075	0.270	0.051	0.012	-0.076	0.262	-0.037	0.019	-0.149	0.006
13	0.009	0.613	0.045	0.420	0.009	0.610	0.044	0.429	-0.116	0.000	-0.016	0.731
14	-0.032	0.361	0.139	0.501	-0.032	0.357	0.139	0.501	0.004	0.884	-0.067	0.676
15	0.077	0.000	0.011	0.834	0.077	0.000	0.011	0.841	-0.002	0.904	-0.057	0.192
16	-0.006	0.759	0.061	0.260	-0.007	0.735	0.060	0.268	0.006	0.699	0.005	0.912
17	0.006	0.788	0.110	0.087	0.006	0.788	0.108	0.092	-0.092	0.000	-0.349	0.000
18	0.040	0.268	0.023	0.766	0.041	0.262	0.024	0.761	0.025	0.381	-0.055	0.372
19	0.008	0.773	-0.019	0.708	0.006	0.811	-0.021	0.677	0.093	0.000	0.070	0.098
Adj. R^2	49.15%		53.05%		68.51%		70.92%		12.04%		18.14%	

H_0: $D_2=D_3=\ldots=D_{19}=0$

F-Stat	20.8895	11.8048	20.9249	11.7815	26.3523	9.3786
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 9. Regression Results: Log of Order Processing Costs

This Table reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is log of order processing costs. See Appendix B, Panel A for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R2 before and after shows the value of adjusted R2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test.

Specialist Firm No	Intercept	Log (# of Trades)	Log (Trade Size)	Log (Market Cap.)	Volatility	Log (Quote Midpoint)	% of Regional Trades	Fund	Foreign	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P value
1	3.794 ***	0.103 ***	0.022	0.033 *	-0.216 ***	-0.297 ***	0.212 *	0.053	-0.090	0.0555	0.0851	3.61	0.000
2	3.582 ***	0.065 ***	0.044 ***	0.045 ***	-0.153 ***	-0.270 ***	-0.022	0.019	0.009	0.0955	0.1469	6.61	0.000
3	3.751 ***	0.026	0.018	0.045 ***	-0.094 ***	-0.160 ***	0.258 **	0.102 **	0.027	0.0628	0.1012	3.03	0.000
4	4.003 ***	0.044 ***	0.006	0.034 **	-0.145 ***	-0.225 ***	0.101	0.117 ***	-0.002	0.0462	0.0830	4.98	0.000
5	4.242 ***	0.076 ***	0.035 *	-0.020	-0.171 ***	-0.143 ***	0.018	0.051	0.019	0.0544	0.0763	2.47	0.000
6	4.250 ***	0.088 ***	0.035	-0.024	-0.267 ***	-0.139 ***	0.102	0.043	0.087	0.0570	0.0854	3.00	0.000
7	3.869 ***	0.131 ***	0.011	0.050 ***	-0.179 ***	-0.384 ***	0.018	0.087 *	0.132 *	0.1331	0.1651	5.40	0.000
8	3.327 ***	0.046	0.033	0.081 **	-0.190 ***	-0.252 ***	0.057	0.094	-0.031	0.1231	0.1422	2.72	0.002
9	4.266 ***	0.010	-0.026	0.043	-0.229 ***	-0.189 ***	0.071	-0.096	0.126	0.0560	0.0923	3.74	0.000
10	4.524 ***	0.075 **	-0.086 ***	0.055 *	-0.152 ***	-0.305 ***	-0.113	0.052	0.132	0.1180	0.1405	3.89	0.000
11	3.601 ***	0.099 *	-0.002	0.031	-0.153 ***	-0.133 *	-0.122	0.134 *		0.0709	0.0726	1.18	0.308
12	3.139 ***	0.051	0.050	0.033	-0.076 ***	-0.128 **	0.151	0.113 *	-0.106	0.0458	0.0910	6.24	0.000
13	3.867 ***	0.072 *	0.064 *	0.001	-0.151 ***	-0.217 ***	0.207	0.061	0.005	0.0805	0.0885	2.34	0.030
14	4.661 ***	0.301 **	-0.024	-0.115	-0.051	-0.192	-0.104	0.477 ***	-0.035	0.0876	0.0686	0.41	0.801
15	3.834 ***	0.016	0.037	0.058 *	-0.174 ***	-0.252 ***	-0.335 *	0.223 ***	0.130	0.0522	0.0653	3.51	0.007
16	4.263 ***	0.056	0.034	0.006	-0.189 ***	-0.213 ***	-0.122	0.044	0.041	0.0645	0.0896	5.58	0.000
17	4.412 ***	0.135 **	-0.048	0.074	-0.215 ***	-0.530 ***	-0.478 **	0.095	-0.186	0.1852	0.1832	0.68	0.564
18	4.185 ***	0.356 **	0.272 ***	-0.353 ***	-0.251 **	0.297	1.884 **	-0.028	0.180	0.1508	0.1445	0.93	0.335
19	4.566 ***	0.019	-0.068	-0.023	-0.171 ***	0.050	0.726	0.008		0.0242	0.0283	2.04	0.155

Table 10. Regression Results for Each Specialist Firm.

This table reports the coefficient estimates for the trading frequency, from estimating equation (3) for each specialist firm.

Specialist Firm	Log(Number of Trades)	(P-Value)
BEAR HUNTER SPECIALIST LLC	0.0768	(0.0000)
BEAR HUNTER STRUCTURED PRODUCTS	0.0646	(0.6518)
BENJAMIN JACOBSON AND SONS LLC	0.0596	(0.1266)
BOCKLET AND CO. LLC	0.0736	(0.0000)
BUTTONWOOD/ALBERT FRIED & CO LLC	-0.0611	(0.2964)
FLEET MEEHAN SPECIALIST INC	0.0479	(0.0000)
FREEDOM SPECIALISTS/ADRIAN/RPM SPE	0.4140	(0.0035)
LABRANCHE & CO/FREEDOM/ADRIAN & CO	0.1360	(0.0000)
LABRANCHE AND CO.	0.1075	(0.0000)
LYDEN, DOLAN, NICK & CO.,LLC.	0.0341	(0.0038)
PERFORMANCE SPECIALIST GROUP, L.P.	0.0715	(0.0000)
RPM SPECIALIST CORP.	0.0983	(0.0016)
SCAVONE,MC KENNA,CLOUD AND CO LLC	0.0374	(0.0086)
SPEAR, LEEDS AND KELLOGG SPEC. LLC	0.0681	(0.0000)
STERN AND KENNEDY	0.1216	(0.0000)
SUSQUEHANNA SPECIALISTS	0.0554	(0.0000)
VAN DER MOOLEN SPECIALIST USA LLC	0.0729	(0.0000)
WAGNER STOTT BEAR SPECIALISTS LLC	0.0552	(0.0000)
WAGNER STOTT MERCATOR LLC	0.0368	(0.0020)
WALTER N. FRANK AND CO. LLC	0.0619	(0.0000)
WEISKOPF, SILVER SPECIALISTS, LLC	0.1243	(0.0000)

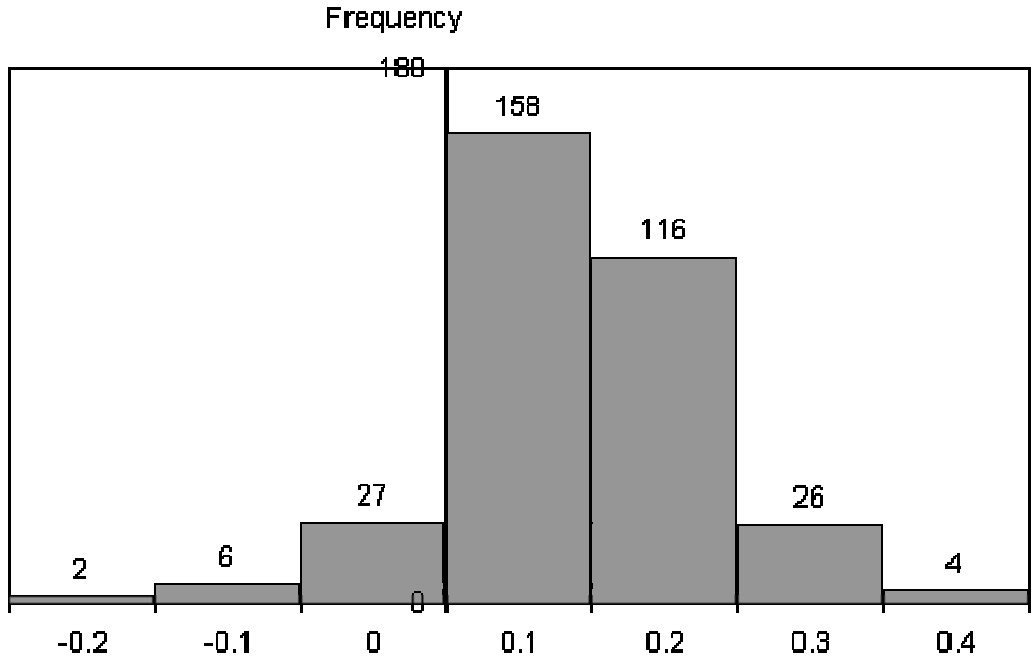
Table 11. Distribution of Estimated Coefficients for Trading Frequency for Individual Specialist Portfolios

This table reports the distribution of coefficient estimates for the trading frequency, from estimating equation (3) for each individual specialist portfolio.

Panel A.

	All Coefficients	Significant Coefficients
Mean	0.09	0.12
Median	0.08	0.11
Minimum	-0.23	-0.23
10th Percentile	-0.01	0.06
20th Percentile	0.03	0.07
30th Percentile	0.05	0.08
40th Percentile	0.07	0.10
50th Percentile	0.08	0.11
60th Percentile	0.10	0.12
70th Percentile	0.12	0.14
80th Percentile	0.14	0.17
90th Percentile	0.18	0.21
Maximum	0.78	0.78
# of negative coefficients	35	11
# of positive coefficients	304	231
# of significant coefficients at the 1% level		184
# of significant coefficients at the 5% level		220
# of significant coefficients at the 10% level		242

Panel B. Histogram of All Estimated Coefficients



Panel C. Histogram of Significant Coefficients

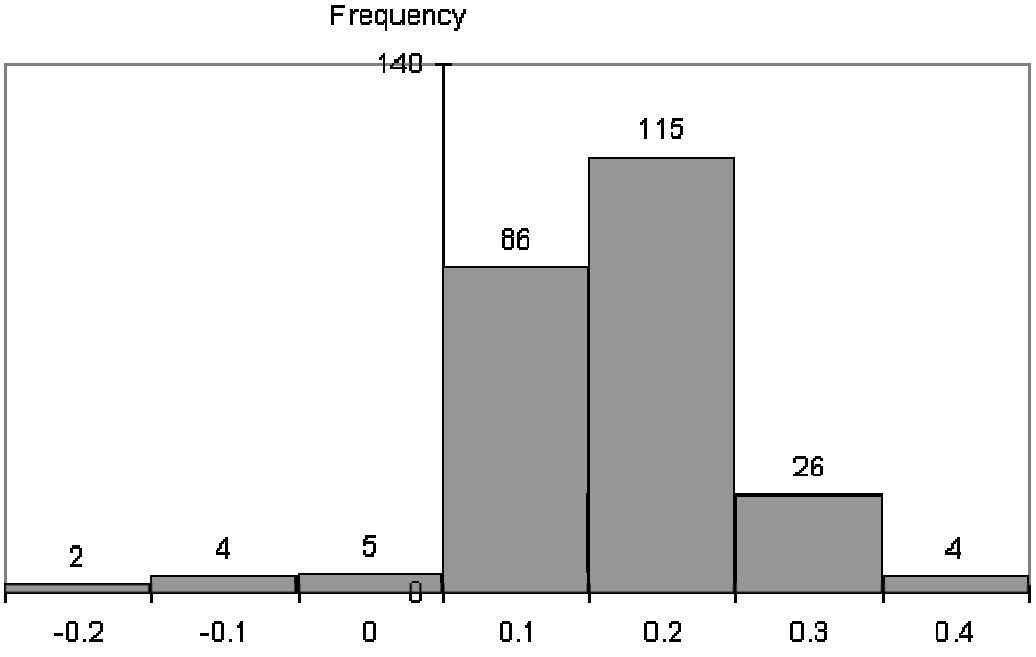


Table 12. Percentage Specialist Participation to the Quotes

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is the average of mean percentage specialist participation at the bid and ask. See Appendix B, Panel B for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Panel B reports the distribution of the estimated specialist dummy coefficients.

Panel A: Percentage Specialist Participation to the Quotes

Specialist Firm No	Intercept	Log(Number of Trades)	Log (Trade Size)	Log(Market Capitalization)	Volatility	Log(Quote Midpoint)	Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-value	Pairwise Tests
1	0.189	-0.017 **	0.008	-0.026 ***	0.049 ***	0.126 ***	0.3459	0.6112	24.49	0.000	69.05%
2	2.123 ***	-0.019 *	-0.009	-0.089 ***	0.022 ***	0.023	0.0617	0.3581	14.87	0.000	98.42%
3	-1.205 **	-0.011	0.027 **	0.053 **	0.013 ***	0.166 *	0.3290	0.5895	14.07	0.000	50.00%
4	0.319 **	0.000	-0.026 **	-0.032 ***	0.042 ***	0.166 ***	0.3582	0.5482	13.65	0.000	91.11%
5	-0.896	-0.019	0.072 ***	0.040	-0.008	0.060	0.2146	0.5078	5.39	0.000	37.78%
6	-1.564 ***	0.004	0.001	0.153 ***	0.009	-0.005	0.2826	0.4902	16.63	0.000	100.00%
7	0.304 *	0.004	-0.048 ***	0.002	0.070 ***	0.033	0.1419	0.2870	8.56	0.000	40.00%
8	4.814	0.029	-0.133 ***	-0.173	0.025	-0.219	0.6503	0.6824	2.15	0.074	0.00%
9	-0.996 ***	-0.004	0.036 ***	0.103 ***	0.010	-0.192 ***	0.4834	0.5804	15.57	0.000	100.00%
10	0.019	-0.055 ***	-0.028	0.011	0.055 **	0.130 ***	0.3855	0.4211	3.54	0.017	100.00%
11	1.333 ***	0.004	-0.020	-0.134 ***	0.098 ***	0.278 ***	0.2924	0.3350	9.14	0.003	na
12	48.620 *	-0.019	-0.030	-5.619 *	0.020	4.776	0.2106	0.2403	2.99	0.090	na
13	8.893 ***	-0.019	-0.006	-1.206 ***	0.062 *	2.482 ***	0.0610	0.1779	17.78	0.000	na

Panel B. Distribution of the Absolute Value of the Estimated Specialist Dummy Coefficients

Specialist Firm No	Mean	Median	Std	Min	Max
1	0.09	0.06	0.10	-0.09	0.31
2	-0.55	-0.54	0.24	-1.03	-0.10
3	-0.04	-0.03	0.19	-0.39	0.38
4	0.05	0.02	0.13	-0.09	0.26
5	-0.11	-0.15	0.14	-0.33	0.16
6	-0.28	-0.30	0.13	-0.46	-0.07
7	0.07	0.04	0.11	-0.03	0.29
8	-1.07	-0.97	0.80	-1.88	0.02
9	-0.04	-0.05	0.24	-0.29	0.22
10	0.12	0.15	0.05	0.07	0.15
11	-0.11	-0.11	na	-0.11	-0.11
12	27.42	27.42	na	27.42	27.42
13	-0.08	-0.08	na	-0.08	-0.08
Average	0.09	-0.03	2.55	-1.88	27.42

Table 13. Percentage Specialist Participation to the Trades

Panel A reports the OLS results from estimating equation (2) for each specialist firm where the dependent variable is the percentage of trades that the specialist has chosen strategy 2 (participate at the quoted price) or strategy 3 (participate at the improved price). See Appendix B, Panel B for the names of the specialist firms and the number of individual specialists employed by each firm. ***, ** and * denotes significance levels at the 1%, 5%, and 10% levels, respectively. Adjusted R^2 before and after shows the value of adjusted R^2 before and after adding the individual specialist dummies. F-stat is the value of F-statistic for the null hypothesis that the coefficients of individual specialist dummies are not statistically significantly different from each other and the p-value is the corresponding p-value for this F-test. Panel B reports the distribution of the estimated specialist dummy coefficients.

Panel A: Percentage Specialist Participation to the Trades

Specialist Firm No	Intercept		Log(Number of Trades)		Log (Trade Size)		Log(Market Capitalization)		Volatility		Log(Quote Midpoint)		Adj. R^2 (Before)	Adj. R^2 (After)	F-Stat	P-value	Pairwise Tests
1	0.754	***	-0.101	***	-0.004		0.013		0.033	**	0.007		0.2436	0.3695	7.67	0.000	40.21%
2	2.118	**	-0.041	*	-0.091	***	-0.036		0.024	**	-0.014		0.1717	0.2104	2.34	0.001	21.05%
3	0.487		-0.075	***	-0.043	**	0.042		0.003		-0.037		0.2260	0.2542	1.77	0.030	14.17%
4	1.035	***	-0.053	*	-0.033		-0.014		0.059	**	-0.042		0.1652	0.4853	17.34	0.000	93.33%
5	1.918	*	-0.090		0.020		0.007		-0.007		-0.919		0.1815	0.2824	1.96	0.048	13.33%
6	-0.992		0.016		-0.055		0.156	**	0.031		-0.012		0.1345	0.1722	2.73	0.006	52.38%
7	-0.022		-0.159	***	-0.076	**	0.130	***	0.105	**	-0.094		0.0875	0.1044	1.62	0.131	0.00%
8	19.081	*	0.128		-0.292	***	-0.526	*	0.117		-2.240		0.2134	0.3465	2.79	0.030	50.00%
9	-1.394	***	-0.053	**	-0.002		0.195	***	0.006		-0.332	***	0.1669	0.2736	10.18	0.000	66.67%
10	1.342		-0.035		-0.050		-0.057		0.038		0.090		0.0987	0.1617	3.93	0.010	0.00%
11	0.162		-0.104	*	0.042		0.015		0.185	***	0.018		0.1790	0.1875	2.22	0.139	na
12	-19.795		-0.062		-0.150	**	3.166		0.161		-5.435		0.3393	0.3250	0.23	0.632	na
13	-0.252		-0.073	**	0.012		0.064		0.081		-0.043		0.0147	0.0101	0.46	0.498	na

Panel B. Distribution of the Estimated Specialist Dummy Coefficients

Specialist Firm No	Mean	Median	Std	Min	Max
1	-0.05	-0.03	0.14	-0.34	0.18
2	-0.39	-0.42	0.14	-0.63	-0.12
3	0.05	0.05	0.07	-0.05	0.16
4	-0.22	-0.26	0.24	-0.55	0.17
5	1.53	1.71	0.63	0.14	2.30
6	-0.29	-0.24	0.16	-0.54	-0.09
7	0.03	0.03	0.13	-0.11	0.19
8	-5.64	-4.58	4.12	-10.83	-0.45
9	0.03	0.00	0.30	-0.25	0.37
10	0.00	-0.10	0.19	-0.12	0.22
11	-0.11	-0.11	na	-0.11	-0.11
12	-14.78	-14.78	na	-14.78	-14.78
13	-0.02	-0.02	na	-0.02	-0.02
Average	-0.33	-0.07	1.99	-14.78	2.30

Appendix A

Information about the sample that consists of 143 stocks we employ to compare specialist strategies.

Symbol	Data Period	Symbol	Data Period	Symbol	Data Period	Symbol	Data Period
AIG	x	FMO	xx	MRK	x	SZ	xx
ALS	xx	FNM	x	MU	x	T	x
AOT	xx	FOE	xx	MWC	xx	TGT	x
AP	xx	FTD	xx	MWD	x	TLM PRB	xx
AVB	xx			MXE	xx	TMK	x
AXP	x	GGT PR	xx	NAP	xx	TRP	xx
AXP PRA	xx	GLW	x	NKE	x	TYC	x
BAC	x	GNA	xx	NOK	x	UBT	xx
BBV	xx	GPS	x	NPC	xx	UDS	x
BK	x	GPT	x	NR	xx	UMG PRY	xx
BKE	xx	GRP	xx	NUI	xx	USI	xx
BPL	xx	GX	x	OFG	xx	VIAB	x
BRM	xx	HD	x	OMX	xx	VOD	x
BZL	xx	HI PRT	xx	ONE	x	VTP	xx
C	x	HIF	xx	OUI	xx	WB	x
CB	x	HPT	xx	PBR	xx	WFC	x
CBA	xx	HRC	x	PCG	x	WMK	xx
CHH	xx	HWP	x	PCS	x	WMS	xx
CLP PRA	xx	IBM	x	PFE	x	WMT	x
CM	xx	IMY	xx	PFP	xx	XOM	x
CMS	x	IRT	xx	PNK	xx	XRX	x
CNC	x	JBL	x	PP	xx	ZNH	xx
CPN	x	JPM	x	PST PRA	xx	ZNT	xx
CQB PRA	xx	JPM PRC	xx	PTM	xx	ZQK	xx
CSD PRA	xx	JW B	xx	Q	x	ZTR	xx
CUZ	xx	KGC	xx	RI	xx		
CWF	xx	KM	x	RKY	x		
DIS	x	KWD	xx	ROM PR	xx		
DL	xx	LMGA	x	SBC	x		
DRE	xx	LNC PRG	xx	SBP PRA	xx		
DRE PRA	xx	LNC PRY	xx	SCH	x		
DUC	xx	LTD	x	SGP	x		
EIX	x	MC	xx	SJI	xx		
ELY	x	MCD	x	SJR	xx		
ENE PRT	xx	MER	x	SKO	xx		
EQT	x	MIJ	xx	SLR	x		
F	x	MKT	xx	SQM A	xx		
FCP	xx	MO	x	SSS PRB	xx		
FIG PRA	xx	MOT	x	SUS	xx		

x : 04/02/2001 - 04/06/2001
xx: 04/02/2001 - 06/29/2001

Appendix B. Specialist Firms

Panel A reports the number of individual specialists employed by each specialist firm for the analysis of differences between specailists in terms of quotes, spreads, depths, and execution costs. Panel B reports the number of individual specialists employed by each specialist firm for the analysis of differences between specailists in terms of their participation strategies in the quotes and trades..

Panel A. Execution Costs

Specialist Firm	No	Number of Specialists
BEAR HUNTER SPECIALIST LLC	7	16
BENJAMIN JACOBSON AND SONS LLC	9	12
BOCKLET AND CO. LLC	12	8
BUTTONWOOD/ALBERT FRIED & CO LLC	19	2
FLEET MEEHAN SPECIALIST INC	4	64
FREEDOM SPECIALISTS/ADRIAN/RPM SPE	18	3
LABRANCHE & CO/FREEDOM/ADRIAN & CO	14	6
LABRANCHE AND CO.	1	82
LYDEN, DOLAN, NICK & CO.,LLC.	15	6
PERFORMANCE SPECIALIST GROUP, L.P.	10	12
RPM SPECIALIST CORP.	6	17
SCAVONE,MC KENNA,CLOUD AND CO LLC	16	6
SPEAR, LEEDS AND KELLOGG SPEC. LLC	2	73
STERN AND KENNEDY	11	10
SUSQUEHANNA SPECIALISTS	13	8
VAN DER MOOLEN SPECIALIST USA LLC	5	51
WAGNER STOTT MERCATOR LLC	3	68
WALTER N. FRANK AND CO. LLC	8	13
WEISKOPF, SILVER SPECIALISTS, LLC	17	5
	Total	462

Panel B. Specialist Strategies

Specialist Firm	No	Number of Specialists
Labranche And Co.	1	30
Spear, Leeds And Kellogg Spec. Llc	2	22
Fleet Meehan Specialist Inc	3	18
Wagner Stott Bear Specialists Llc	4	12
Wagner Stott Mercator Llc	5	12
Performance Specialist Group, L.P.	6	9
Van Der Moolen Specialist Usa Llc	7	8
Bear Hunter Specialist Llc	8	6
Susquehanna Specialists	9	5
Walter N. Frank And Co. Llc	10	4
Bocklet And Co. Llc	11	2
Labranche & Co/Freedom/Adrian & Co	12	2
Scavone,Mc Kenna,Cloud And Co Llc	13	2
	Total	132

BÜLENT KÖKSAL
Curriculum Vitae
May 2005

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4209 Cherry Orchard Court
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EDUCATION

Ph.D., Economics, Indiana University, Bloomington, May 2005

* Dissertation Topic: "Three Essays on NYSE Specialist Strategies"
* Dissertation Chair: Professor Craig Holden, Finance Department, Kelley School of Business, Indiana University

M.A., Economics, Indiana University, Bloomington, December 2002

M.A., Economics, Fatih University, Istanbul, Turkey, July 1999

B.Sc., Mathematics Education, Bogazici University, Istanbul, Turkey, June 1996

FIELDS OF SPECIALIZATION

Finance

Econometrics

Development Economics

Monetary Economics

RESEARCH

- "Participation Strategy of the NYSE Specialists to the Posted Quotes", Working Paper
- "Participation Strategy of the NYSE Specialists to the Trades", Working Paper
- "Differences in Individual NYSE Specialists' Performances and Strategies", Working Paper
- 'The Impact of Monetary Policy on Bank Balance Sheets", MA Thesis

CONFERENCE PRESENTATIONS

Presenter, "Participation Strategy of the NYSE Specialists to the Posted Quotes", Financial Management Association Meetings, New Orleans, October 2004

AREAS OF INTEREST

Research: Market Microstructure, Asset Pricing

Teaching: Investments, International Finance

TEACHING EXPERIENCE

Department of Economics, Indiana University Purdue University Indianapolis

Fall 2004, Adjunct Instructor (taught Microeconomics with full responsibility)

Department of Economics, Indiana University

Fall 2000 - Spring 2004, Associate Instructor
(taught Microeconomics and Statistics with full responsibility)

Fall 1999 - Spring 2000, Graduate Assistant

Fatih University, Istanbul, Turkey

Fall 1997 - Spring 1999, Teaching Assistant (Economics)

Fall 1997 - Spring 1998, Instructor, Department of Information Technologies

Other Teaching

Fall 1996 – Spring 1997, Mathematics Teacher, Tashkent Boys' High School,
Tashkent, Uzbekistan

January 1996 – June 1996, Teaching Intern, Atanur Oguz High School, Istanbul, Turkey

LANGUAGES

English, Turkish (Native)

COMPUTER KNOWLEDGE

SAS, Stata, Limdep, MS Office applications

PROFESSIONAL AFFILIATIONS

American Finance Association

Western Finance Association

Financial Management Association

REFERENCES

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