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A Specialist's Quoted Depth and the Limit Order Book*

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A Specialist's Quoted Depth and the Limit Order Book

The goal of this paper is to investigate whether specialists use quoted depth as a strategic choice variable. In particular, the paper investigates whether specialists manage quoted depth to reduce risks associated with information events. In order to study specialists' behavior, quoted depth must be partitioned into the depth provided by the specialist and depth in place on the limit order book. To accomplish this partitioning, estimates of limit order books are compiled. The analysis details how specialists update their quotes in relation to an evolving limit order book. In addition, the analysis conducts an event study which shows that both specialists and limit order traders reduce depth around earnings announcements thereby reducing their exposure to adverse selection costs. The results also show that the specialists selectively supply liquidity by reflecting the interest on the limit order book on the side (or sides) of the market where they believe there is a chance of informed trading. Changes in quoted depth are shown to be consistent with specialists managing their inventory positions as well as having knowledge of the future value of the stock.

I. Introduction

Much market micro structure literature demonstrates how a specialist uses quoted prices as an instrument to manage inventory, mitigate the adverse selection problem, and promote price discovery. Well known examples include Garman (1976), Amihud and Mendelson (1980), Glosten and Milgrom (1985), and Leach and Madhavan (1992).

Equally important, but less investigated, is the quantity aspect of a specialist's price schedule. A specialist posts a bid depth and an ask depth, in addition to the bid and ask prices, which specify the maximum quantities for which the respective prices apply. Specialists change their quoted depth in ninety percent of all quotes changes, moreover, fifty percent of all quote changes are unaccompanied by changes in quoted prices. Therefore, specialists actively manage their quoted depths even when prices are not changing.

The primary objective of this paper is to empirically investigate whether specialists use depth as a strategic choice variable to regulate the amount of liquidity they provide. Other important suppliers of liquidity, and competitors to specialists, are public limit orders. Given the public order precedence rule (see ¶ 2092 of the NYSE Rules), limit orders at the quoted prices have priority over the specialist's interest. Consequently, to analyze depth contributed by the specialist at any point in time, it is necessary to have an estimate of the limit order book that the specialist is maintaining. The difference between the quoted depth and the depth on the limit order book is the specialist's contribution to depth.

The results show that specialists selectively supply liquidity by reflecting the interest on the limit order book on the side (or sides) of the market where they believe there is a chance of informed trading. By posting a price schedule that mirrors the volume at the best buy and sell limit order prices, specialists ensure that any trader demanding immediacy will be crossed with limit orders on the limit order book rather than with their inventory. Changes in quoted depth are shown to be consistent with specialists managing their inventory positions as well as having knowledge of the future value of the stock. Finally, both specialists and limit order traders reduce depth around earnings announcements thereby reducing

their exposure to adverse selection costs.

This work is related to a number of areas of ongoing financial research. On the theoretical front, early work that addressed the quantity aspect of a specialist's price schedule took quantities as exogenous and proceeded to solve for the equilibrium price for each quantity abstracting from any interaction with a limit order book. Examples include Easley and O'Hara (1987) who assumed two possible quantities (large and small) and Glosten (1989) who solved for the complete price/quantity function. More recent work by Rock (1990), Kumar and Seppi (1994) and Seppi (1997) advance the basic model by incorporating the interaction between the specialist and the limit order book, yet their models provide no role for the specialist's quoted depth. Another tact taken by Dupont (1994) and Kavajecz (1996) is to start with the assumption that the specialist posts a price schedule, in the absence of a limit order book, which specifies a bid, bid depth, ask and ask depth. This schedule specifies that the specialist is willing to purchase (sell) shares at the bid (ask) up to the amount specified by the bid (ask) depth. The advantage of this construct is twofold. First, it matches the actual price schedules posted on the New York Stock Exchange (NYSE) and, second, it endogenizes the quantity aspect allowing it to be a choice variable of the specialist. Dupont and Kavajecz suggest that one reason a specialist may move his depth quotes is to reduce adverse selection costs. This paper combines the specialist/limit order book interaction of the Rock (1990), Kumar and Seppi (1994) and Seppi (1997) models with the strict specialist price schedule of the Dupont (1994) and Kavajecz (1996) models.¹

The remainder of the paper is organized as follows. Section II describes the TORQ data set and the procedure used in constructing the estimates of the limit order book. In addition, descriptive statistics provide cross-sectional properties of the constructed limit order books. Section III details the interaction

¹There is also a growing empirical literature on limit order books; however, this literature's primary focus has been pure limit order book markets rather than specialist markets. Examples include: Niemeyer and Sandås (1993), Stockholm; Hedvall (1994), Helsinki; Lehmann and Modest (1994), Tokyo; Niemeyer (1994) Helsinki/Stockholm; Biais, Hillion and Spatt (1995), Paris; DeJong, Nijman and Roell (1995), Paris; Frino and McCorry (1995), Australia; Hamao and Hasbrouck (1995), Tokyo; Hollifield, Miller, Sandås (1996), Stockholm; and Sandås (1996), Stockholm.

between the specialist and the limit order book for one stock on the day of a quarterly earnings announcement. The example demonstrates a number of properties that will be shown to hold more generally. Section IV performs the empirical test of depth contribution around information events. Section V concludes.

II. Limit Order Book

A limit order directs a broker (or exchange) to purchase (sell) a specified quantity at the best available price not to exceed a maximum (minimum) acceptable price. A limit order book is a collection of limit orders submitted by traders that is maintained by the exchange (or specialist if at the NYSE) pending execution or further action by the issuers.² By submitting a limit order a trader is providing other market participants with the ability to execute against his limit order. This is the sense in which limit orders provide liquidity to those who demand immediacy. The limit order book is crucial to the analysis of depths because, as a matter of trading protocol, the specialist is required to better any limit order price before he can take the trade himself (see ¶ 2092 of the NYSE Rules). To assess whether the specialist or the limit order book is supplying the liquidity in the market, one must compare the specialist's quotes with the best limit orders on both sides of the market.

II.1 Data and Methodology

The TORQ (Trades, Orders, Reports, and Quotes) database covers 144 NYSE listed securities over the three months, November 1990 through January 1991. As its name suggests, the TORQ data set contains information on all trades that took place, all orders that were placed via one of the automated routing systems, a detailed report of the counter parties to transactions and the specialist's prevailing

²The limit order book originally got its name because it was in fact a ledger that the specialist carried and logged limit orders.

quotes.³ The data on the orders allow for the construction of an estimate of the limit order book. The estimate is incomplete in the sense that the data only include orders that are placed through one of the automated routing systems. Orders brought to the floor via a floor broker are not included. Table 1 contains a list of the stocks in the TORQ sample. Firms are separated into deciles with fifteen in each of the first four deciles and fourteen in each of the six remaining deciles. Stocks are ranked by average daily trading volume over the sample period.⁴

The TORQ database contains three major types of records: orders, executions and cancellations. Each order record specifies among other things, the date and time of submission, the type of order, the order quantity, and the limit price. Execution and cancellation records provide similar information about the underlying order as well as information specific to the execution or cancellation, such as the execution (cancellation) date and time and quantity executed (canceled). The principle behind the limit order book estimation is that at any instant in time, the limit order book should reflect those orders remaining after the orders placed prior to the time in question are netted with all prior execution and cancellation records.

The estimation is done in four steps. The first step entails identification of existing limit orders at the time the sample started; these are limit orders submitted prior to November 1, 1990 which up to that point had not been executed or canceled. I call this the prebook. Since the orders sought were placed prior to the start of the database, there are no corresponding order records included in the database. Instead, I must infer the existence of the order from subsequent execution and cancellation records. The prebook is constructed by searching over all available records for a given stock and retrieving any execution or cancellation records which refer to an order placed prior to the start of the sample period.

³This data does not give an estimate of the specialist's inventory.

⁴Decile rankings were also done using CRSP data on market capitalization at the 1990 year end. These alternative rankings can also be found in Table 1. Although the results are largely the same under either ranking mechanism, trading activity seems to be a better predictor of limit order book properties.

Those records are then converted into order records making up the existing limit order book at the beginning of the sample period.

After the prebook is constructed, current records in the database are processed. To estimate the limit order book for a given date and time, all records with a date and time stamp prior to the chosen date and time are selected and separated into their respective categories: orders, executions and cancellations. The second step in the procedure adds the current orders to the prebook; the result is a listing of all known orders placed prior to the chosen date and time.

Step three entails matching order records with execution records. Recall that execution records contain all the information about the underlying order. This makes it possible to determine which orders were executed. Those orders having matching execution records are eliminated. The remainder are orders or residual orders that were unexecuted prior to the chosen date and time.

The last step performs the analogous procedure using cancellation records. Current cancellation records are matched with the remaining order records and any order with a matching cancellation record is eliminated.⁵ The remaining order records are orders that were placed prior to the chosen date and time and were not executed or canceled in entirety.⁶ This residual is the limit order book estimate for the chosen stock at the chosen date and time.

Not all the execution and cancellation records match up to orders as they should. Moreover, orders remain on the limit order book that clearly should have been either executed or canceled. An example of this problem is when there is a buy order on the limit order book that is above the posted ask. This scenario would warrant immediate execution of the 'misplaced' order. Problem records such as these are eliminated. These problems could have arisen from typographic errors or missing records, both of

⁵Executions are handled before cancellations because execution records provide more fields to match with the original order; therefore it is harder to mismatch an execution than it is to mismatch a cancellation.

⁶There are partial executions and partial cancellations. This entails an execution or cancellation of a fraction of the original order, where the residual order remains as an active limit order.

which would make matching records impossible. Table 2 shows the average number of records processed for each decile and the average percentage of each record type that is discarded. In addition, the analysis is done on an individual stock basis in the lower panel. The median stock has less than one half of one percent (0.48%) of their records discarded with the worst case discarding 4.17% of its total records. The fact that the vast majority of the records match up exactly suggests the procedure provides a fairly clean estimate of the limit order book.

A limit order book is estimated at thirty minute intervals for all sixty-three business days in the sample period yielding a maximum 882 limit order book estimates for each of the 144 stocks in the sample.⁷ Table 3 provides an example of one such limit order book for Federal Express on November 21, 1990 at 12:00 Noon. The exhibit is organized with sell orders in the upper left corner and buy orders in the lower right corner. The limit orders are listed in increasing price/time priority on the ask side and decreasing price/time priority on the bid side. Each order specifies: the date and time (if known) of placement, the side of the market [regular sell orders (SEL), short-sales (SST) and buy orders (BUY)], the duration of the order [good-until-canceled (GTC) and day], the number of shares, and the limit price.⁸ Between the buy and sell limit orders the prevailing NYSE quote and the best Non-NYSE quote are listed.⁹

As a bit of an introduction, as well as an illustration of some the recurring themes of this paper, note the following. First, the specialist is providing liquidity only on the bid side of the market. On the sell side, the two best limit orders at 32% totaling 2,100 shares is more than the ask depth posted by the

⁷Estimates were calculated at the time of the opening quote and are calculated each half-hour on the half-hour thereafter. For example, if a stock opened at 9:40:28 AM, an estimate would be taken at that time and then estimates would be done at 10:00:00, 10:30:00, etc. The number of limit order books for each stock is approximate because occasional late openings (later than 10:00:00) causes differences in the number of estimates for each stock.

⁸Time of placement is not known for orders placed prior to the start of the database.

⁹The Non-NYSE trading venues are: Boston, Cincinnati, ITS, Midwest, Instinet, Pacific, NASD and Philadelphia. Note that not all Non-NYSE venues make a market in all stocks. The calculation of the best Non-NYSE quote is done independently on the bid and ask side of the market.

specialist. In contrast, the specialist is posting a bid depth of 5,000 shares of which 1,100 is attributed to the limit order book and the additional 3,900 shares is attributed to either the specialist or floor traders. Second, in addition to the NYSE specialist and limit order book, liquidity may also be supplied by Non-NYSE trading venues; however, the best Non-NYSE quotes often entail worse prices and substantially smaller depths. Lastly, one can see from the dates and times that orders are placed on the book, that the majority of limit order activity takes place at or near the best bid or best ask.

II.2 Limit Order Book Summary Statistics

This section investigates the potential for liquidity provision that the limit order books have on the NYSE. For instance, do the limit order books have sufficient shares to be meaningful providers of depth? Table 4 shows the aggregate amount of depth provided by the limit order book. The table displays the average number of orders and the average total volume expressed both in shares and as a percentage of average daily trading volume. The figures suggest that there is a substantial number of shares pledged on these limit order books, with a minimum of a block (10,000 shares) on both sides of the market for all but the smallest stocks.¹⁰ In addition, the average number of orders imply that the composition of limit order books is made up of increasingly larger orders as the stocks get smaller (less frequently traded). Even though these stocks have fewer shares on their limit order books, they are able to accommodate a much larger fraction of average daily trading volume than are the larger stocks.

Although the limit order books seem to provide a good deal of depth, what really matters is the amount of depth provided *at* the market. It is this depth that is crucial when comparing the specialist's depth quotes with the book. Table 4 also describes the depth at the best bid and ask limit prices. As a percentage of the total volume on the book, depth at the market ranges from nine percent to fifty percent.

¹⁰The significantly larger volume in the 'Large' decile is driven by six stocks: Boeing (BA), General Electric (GE), International Business Machines (IBM), Philip Morris (MO), American Telephone and Telegraph (T), and Exxon (XON). These are the only stocks in the sample included in the Dow Jones Industrial Average.

Interestingly, the percentage of depth at the market is larger for the stocks with the lowest average daily trading volume.

Table 5 investigates the spread on the limit order book as well as the dispersion of shares away from the best prices. The spread on the limit order book can be very large, both in terms of dollars and percentages, averaging \$0.75 or 7.96% across all stocks. Contrast that with the specialist's quoted spread which averages \$0.23 or 3.96%. This suggests that the specialist plays an important role in narrowing the spread that market participants face when demanding liquidity especially for smaller (less frequently traded) stocks.

The outside columns of Table 5 display the dispersion of volume on the buy side and sell side of the book. The dollar dispersion on the buy side of the book is the dollar difference between the best buy side limit order price and the volume weighted limit price on the buy side of the book. The dollar dispersion on the sell side is defined analogously. The percentage dispersion is the dollar dispersion divided by the limit order book's bid-ask midpoint. Notice that the buy side has a dispersion of \$1.55 or 9.53% while the sell side has a dispersion of \$1.66 or 24.63%. Although the difference between the percentage dispersions is significant at the 0.1% level it may simply be an artifact of the stock price being bounded at zero on the buy side and unbounded on the sell side.

III Evolution of a Limit Order Book

This example follows a sequence of market snapshots that highlights how both the limit order book and the specialist's quotes evolve through time. The strength of presenting an example is that it does not wash away the subtleties of the interaction between the specialist and the limit order book that aggregation often does; however, the weakness of presenting an example is its lack of generality. The generality of the example characteristics are investigated in the next section.

The subject is Waban Incorporated, stock symbol WBN. Waban was created in June 1989 when Zayre Corporation spun off its Warehouse Club division, consisting of HomeClub and BJ's Wholesale

Club, to its shareholders.¹¹ Waban's stock began trading on the NYSE on June 15, 1989. I focus on the day of the 1990 third quarter earnings report announced on Tuesday, November 13, 1990 at 11:05 AM EST. Figures 1 through 4 detail the progression of the limit order book and specialist's quotes at 10:30AM, 11:00AM, 11:10AM, and 1:00PM respectively. The figures presented here are organized much like the Federal Express example shown in Table 3, with the exception that the limit order books are aggregated by limit price.

November 13, 1990 at 10:30 AM

The specialist's quote at 10:30AM is $8\frac{7}{8}$ ask and $8\frac{3}{4}$ bid, with an ask depth of 3,000 and a bid depth of 5,000, see Figure 1. The limit order book also has an $\frac{1}{8}$ spread with the best sellside limit orders posting 6,000 shares and the best buy-side limit orders posting 650 shares.¹² The specialist is providing additional depth on the bid side of the market by contributing 4,350 shares and is not reflecting the full interest on the limit order book on the ask side of the market.¹³ The strategy of posting the same price and the same depth (or in this case, smaller depth) as the best sellside limit order insulates the specialist from any informed traders wishing to purchase shares, since the specialist is able to, and in fact must, pass the purchase order through to cross with the 6,000 shares at $8\frac{7}{8}$.¹⁴

¹¹HomeClub, currently named Homebase, is a merchandiser of home improvement products and building supplies. Homebase stores are located in the Western and Southwestern United States. BJ's Wholesale Club is a membership warehouse club chain located in the Northeastern United States, selling food and general merchandise at discount prices.

¹²The sides of the market are stated from the perspective of a liquidity provider. The specialist or limit order trader buys at the bid and sells at the ask. Therefore, the sellside of the limit order book competes with the specialist's ask side of the market and the buy-side of the limit order book competes with the specialist's bid side of the market.

¹³There are a number of reasons why a specialist may not reflect the full interest on the limit order book in the posted quotes: (1) a trader can request that his limit order not be reflected in the quotes, (2) it could be an error in the estimation of the book and (3) since at this time the specialist was not required to reflect the depth in his quotes he could be acting strategically.

¹⁴This discussion of liquidity provision ignores any interactive mechanism that specialists can use to supply liquidity, for instance, stopping an order or providing price improvement. For an detailed discussion of these topics see Ready (1996).

November 13, 1990 11:00 AM

Figure 2 shows the limit order book at 11:00 AM, five minutes prior to the earnings announcement. The limit order book maintains its spread of $\frac{1}{8}$ at $8\frac{7}{8}$ ask and $8\frac{3}{4}$ bid, but the specialist widens his spread to $\frac{1}{4}$ by posting 9 ask and $8\frac{3}{4}$ bid. Consistent with the earlier figure, the specialist provides no depth on the ask side and adds 1,400 shares to the depth already provided by the book on the bid side. Notice that the specialist has left sellside orders totaling 9,000 shares hidden at $8\frac{7}{8}$. This phenomenon of hidden limit orders highlights two important ideas that have received attention in the micro structure literature.

First, it demonstrates the importance of the effective spread (versus the posted spread) and illustrates one of the reasons trades receive price improvement. Petersen and Fialkowski (1994) and Angel (1994) show that a better measure of the true transactions costs market participants face is the effective spread. For example, in Figure 2, the effective spread is $\frac{1}{8}$, if a market buy order was submitted and was executed against the hidden limit orders at $8\frac{7}{8}$, the market order is said to have received an $\frac{1}{8}$ price improvement. Angel estimates that if hidden limit orders like the ones shown here, were reflected in quotes, the rate of price improvement would fall by fifteen percent.

Second, the example shows the specialist backing away from any incoming purchase orders leaving the limit order book, and in particular the hidden orders, to take the brunt of any potential informed buying. The positioning of the specialist's quotes relative to the limit order book provides an excellent example of the '*second adverse selection problem*' described in Rock (1990). Rock shows that in a model with a specialist and a limit order book competing for order flow, the specialist has an incentive to take the profitable trades and pass the unprofitable ones on to the limit order book. Not only must the limit order traders take into account the unconditional probability of trading with someone who is better informed, the specialist makes the problem more acute by siphoning off the uninformed orderflow and passing on the informed orderflow. This is also reminiscent of the Seppi (1997) model. In Seppi's model, the specialist allows an incoming market order to cross with the limit order book for limit

prices less than or equal to the clean-up price (p^*), or equivalently, for order sizes less than or equal to the minimum volume threshold (S_j). Residual shares are then executed against the specialist inventory at the clean-up price. The clean-up price in this example would be nine and the minimum volume threshold would be 9,000 shares.

November 13, 1990 11:10 AM

At 11:05 AM, Waban announces that third quarter earnings increased ten percent over the previous year's third quarter earnings. Within five minutes of the announcement the specialist's schedule reflects a $\frac{1}{4}$ point increase leaving the prices at $9\frac{1}{4}$ ask and 9 bid, see Figure 3. The specialist's contribution to depth becomes 0 shares and 1,000 shares for the ask and bid side respectively. Even though the limit order book widens its spread to $\frac{3}{8}$, the specialist continues to post an ask price that is $\frac{1}{8}$ higher than the best sell side limit order. In other words, the specialist again allows the limit order book to be the counter party to any purchase order demanding immediacy. The record of limit order book activity over the last ten minutes reveals that there were three buy limit orders executed for 400, 1,000 and 3,000 shares. The 400 and 1,000 share orders were executed against market sell orders and the 3,000 share order was crossed with limit sell orders. Over the same time period, there were twenty-three sell limit orders executed totaling 38,200 shares (13,900 shares of new orders and 24,300 shares of existing orders). Of the 38,200 shares, 1,500 shares were executed against market purchase orders, 3,000 shares crossed with limit purchase orders and the remaining 33,700 shares have no apparent counter party on the buy side of the market. This discrepancy reveals that either floor brokers, or possibly the specialist, took the opposite side of those sell orders by purchasing the stock.

November 13, 1990 1:00 PM

By 1:00 PM the specialist's prices edge up $\frac{1}{8}$ to $9\frac{3}{8}$ ask and $9\frac{1}{8}$ bid, see Figure 4. Now the specialist's depth contributions are 800 shares on the ask side and 5,000 shares on the bid side. The best limit order book prices are unchanged at $9\frac{3}{8}$ and 9, yielding a limit order book spread of $\frac{3}{8}$. The fact that the specialist is comfortable posting more depth than the limit order book on both sides of the market may

signal that the uncertainty associated with the announcement is subsiding. Interestingly, a segment ran in the *Investor's Daily* on November 14, 1990 reporting that Waban's stock rose $\frac{7}{8}$ on the news that third quarter profits were up ten percent. In addition, the story stated that "... the stock has been under accumulation by insiders."

Figure 5 provides a comprehensive summary of the interaction between the specialist's quotes and the best limit orders for the times discussed in the example as well as additional times surrounding the announcement. Specifically, the figure shows that the specialist's posted spread increases ahead of the earnings announcement and remains at that wider level until much of the uncertainty associated with the earnings announcement is resolved (Panel 1). A comparison of the specialist's and limit order book's contribution to depth over this period reveals that the limit order book is providing the liquidity on the ask side (Panel 2) and the specialist is providing the liquidity on the bid side (Panel 3).

In summary, the Waban example illustrates how a specialist can use his depth quotes to eliminate any unwanted trades by passing them on to the limit order book. Furthermore, this can be done on only one side of the market if necessary. Lastly, the scenario outlined in the example is consistent with the idea that the specialist may have good information about the future direction of the stock price.

III.1 Generalization of Example Characteristics

Although useful for intuition, the example provides only a single case. This section investigates the generality of the example characteristics and the potential causes. The Waban example demonstrates how specialists can position their quotes to reflect the interest in the limit order book thereby reducing their exposure to adverse selection costs. Table 6 investigates how often specialists position their quotes in this way. Columns one through four of Table 6 partition the buy-side into four cases, columns seven through ten partition the sell-side analogously. The first and seventh columns show the percentage of time when the specialist's price are inferior to the best limit order on the buy-side and sell-side

respectively. These columns depict instances when there are hidden limit orders.¹⁵ The second and eighth columns show the percentage of time that the specialist posts a price equal to the best limit order and a depth quote that is less than or equal to the volume of shares on the book at that price. Here, the specialist's quotes are mirroring the interest on the limit order book. The specialist is immune from any adverse selection costs since he is required to pass orders on to the book. The third and ninth columns show the percentage of time that the specialist posts the same price as the best limit order and the posted depth is greater than the volume on the book at the best limit order. The difference between the quoted depth and the depth on the book is the additional depth provided by the specialist.¹⁶ Lastly, column four and ten show the percentage of time that the specialist posts a better price than what is on the limit order book. The specialist is providing 100 percent of the depth at the market. On one hand, Table 6 shows that the specialist is either providing additional depth or bettering the price, between fifty and seventy-five percent of the time. On the other hand, between twenty-five and fifty percent of the time, the specialist effectively removes himself from one side of the market; therefore, the specialist is not systematically reflecting the book, rather he is selectively providing liquidity and selectively protecting himself from the market¹⁷. Columns five and six give information on the depth provided on the buy side by the limit order book and by the specialist respectively. Columns eleven and twelve provide similar information for the sell side. Conditional on posting the best available price, both the specialist and the limit order book are credited with the volume for which they would be the counter party should a trader

¹⁵ For an example of hidden limit orders see Figure 2.

¹⁶ Greene (1995) provides an algorithm to infer transactions crossed with limit order book. Assuming the specialist is likely to adjust his depth quote when he is reflecting some portion of the depth on the limit order book and that depth is subsequently altered, we see that the percentages obtained from summing columns one, two and three (seven, eight and nine) are broadly in line with the 77.36% (mean) and 50% (minimum) success rate of his algorithm.

¹⁷ Cao, Choe and Hatheway (1997) argue that there are important differences in the behavior of specialist firms. In principle, differences in the choice to reflect the limit order book in the posted price schedule could be driven by this effect; however, in practice 34 specialist firms are represented in the TORQ sample with no one specialist firm maintaining a majority in any one decile.

wish to trade. These columns reveal that both the limit order book and the specialist provide essential liquidity to the market. In general, the book provides more of the depth for the smaller (less frequently traded) stocks and the specialist provides more of the depth for the larger (more actively traded) stocks. This is consistent with the idea that smaller (less frequently traded) stocks tend to have both higher inventory costs and greater risks of informed trading; therefore, the specialist protects himself by reflecting the interest in the limit order book more often.

Another way quoted depths can be used strategically is to compete for orderflow across exchanges. A good example of this strategic use of depths are Non-NYSE quotes. Typically, Non-NYSE trading venues match the NYSE's prices but post significantly smaller depth. This allows the Non-NYSE venues the opportunity to participate in the uninformed/retail orderflow while avoiding the informed orderflow. Table 7 compares quotes at Non-NYSE venues to quotes at the NYSE. Approximately ninety percent of the time, the Non-NYSE trading venues either post inferior prices or match the NYSE prices and post smaller depth quotes. Furthermore, the differences in posted depth are substantial. Consequently, there is a large difference in the conditional depth, provided by the NYSE and the Non-NYSE trading venues.¹⁸ The following simple exercise provides the most compelling evidence of this phenomenon. After grouping all the available quotes from the TORQ database by the originating exchange regardless of the stock, a frequency distribution was calculated for the posted depths. The 95th percentile for the posted depth on each of the trading venues is as follows: Boston 100; Cincinnati 5,000; Midwest 1,000; NYSE 45,000; Pacific 2,000; Philadelphia 100. Both the Boston and Philadelphia exchanges post the minimum depth of 100, ninety-five percent of the time across all stocks in the TORQ sample.¹⁹ Even though the other trading venues post larger depth, they too are considerably smaller than

¹⁸The specialist's contribution to depth plus the limit order book's contribution in Table 6 does not sum to the depth attributed to the NYSE in Table 7 because the NYSE figures are the quoted depths while the specialist and limit order book contributions may be greater or less than the quantity posted.

¹⁹Market makers on competing exchanges are allowed to 'trade-through' a quote posted for 100 shares on the Intermarket Trading System (ITS). This violation of price priority is allowed because quotes posted for the minimum depth of 100 shares are typically autoquotes, which mirror the prices on a competing exchange.

the comparable NYSE figure.

Thus far I have demonstrated two ways quoted depths can be used by a market makers to compete against other liquidity providers, whether the other liquidity provider is the limit order book or another exchange. What remains to be answered is *when* and *why* the market maker chooses to use this tool. For the remainder of this section the analysis focuses on two possible rationales why a specialist might chose to reflect the limit order book in his quotes. First, the specialist may be actively managing his inventory position by taking on larger buy orders and/or curtailing sell orders if his inventory is too short or by taking on larger sell orders and/or curtailing buy orders if his inventory is too long. Second, the specialist could be informed about the direction of the stock price. Positioning the price schedule to reflect the limit order book on the sellside as well as adding depth on the buy side when the stock is undervalued shields the specialist from being the counter party to informed traders and simultaneously positions himself to purchase undervalued shares. Positioning the price schedule using the opposite strategy would exploit an overvalued stock for the same reasons. These two possible rationales are investigated in turn.

Since tests of inventory management cannot be done directly due to a lack of inventory data, any test must condition on some observable variables that impact the specialist's inventory position. One simple conditioning rule would be to condition on changes in the posted bid and ask. Consider the following scenario. Suppose prices have been rising due to buying pressure or falling due to selling pressure, and assume that the specialist has been providing at least some of the liquidity, then over this period, the specialist's inventory position would be reduced if prices were rising and increased if prices were falling. Actions that are consistent with inventory management are for the specialist to reflect the sellside of the limit order book after prices have been rising to curtail further reductions in his inventory and to reflect the buy side of the limit order book after prices have been falling to curtail further increases in his inventory. The top panel of Table 8 conditions the limit order book/quote sample on two consecutive *prior* price increases (columns one through four) and decreases (columns five through eight).

The table provides a break down of the sample by whether the specialist is reflecting the limit order book on both sides, the sellside (ask side), the buy side (bid side), or whether the specialist is adding liquidity on both sides of the market. Comparing the specialist's quotes after rising prices to those after falling prices reveals that although there is little difference in the percentage of times the specialist is reflecting both or neither sides of the limit order book, there is a difference between the percentage of time the specialist reflects either the sellside or the buy side. Consistent with the inventory management scenario, the specialist is more likely to reflect the sellside of the book when prices in the previous hour were rising and is more likely to reflect the buy side of the book when prices in the previous hour were falling. The difference between the percentage of time the specialist is reflecting the sellside (buy side) after rising prices and the percentage of time the specialist is reflecting the sellside (buy side) after falling prices is significant at the 0.1% (0.5%) level.

The lower panel of Table 8 conditions on *subsequent* price changes rather than *prior* price changes. Much like the upper panel, there is little difference between the full sample figures for reflecting both or neither sides of the book across rising or falling prices. Moreover, the differences between the percentage of time the specialist reflects the sellside (15.83% prior to rising prices and 21.75% prior to falling prices) and the percentage of time the specialist reflects the buy side (25.92% prior to rising prices and 15.45% prior to falling prices) are both significant at the five percent level. These results are consistent with the specialist's duty to 'lean against the wind', in the sense that he is a willing buyer when other traders want to sell and a willing seller when other traders want to buy. They are also consistent with the specialist managing his inventory. The specialist is willing to sell (curtail buying) more often ahead of price increases and is more willing to buy (curtail sales) more often ahead of price decreases. These results are consistent with Madhavan and Smidt (1993), Hasbrouck and Sofianos (1993) and Madhavan and Sofianos (1994), who collectively find evidence of inventory management by specialists. The results shown here serve to reinforce the argument made by Madhavan and Sofianos (1994) that inventory management is a passive pursuit of the specialist and is often accomplished "by selectively

timing the magnitude and direction of their trades rather than by adjusting prices.”

The other possible reason for the positioning of the specialist's quotes is information about the future value of the stock price. The idea that the specialist is well informed about the value of the stock is not a new one. Benveniste, Marcus and Wilhelm (1992) argue that the specialist often has very good information about the market participants and what they know about the underlying value of the asset. Reviewing Table 8 in light of the information hypothesis reveals that although the upper panel is consistent with the inventory hypothesis it is also consistent with the information hypothesis. Curtailing sales and promoting purchases after rising prices and curtailing purchases and promoting sales after falling prices helps the specialist avoid being the counter party to unprofitable (informed) trades as well as take on profitable (uninformed) trades. In contrast, although the lower panel is consistent with the specialist using his inventory to cushion price changes, it is inconsistent with the information hypothesis. For example, if the specialist knew that prices would be rising over the subsequent hour, he would minimize sales by reflecting the sellside of the book and maximize his potential to purchase undervalued shares by pledging depth on the buy side of the book. The results demonstrate the exact opposite reaction by the specialist. In summary, the results from Table 8 are consistent with specialists positioning their quotes to reflect the interest in the limit order book in order to manage their inventory position.

Although Table 8 provides insights into the information hypothesis, it is a coarse test because conditioning on price changes means that only a subset of the limit order book/quote sample is used. Table 9 presents a more refined and comprehensive test of the information hypothesis that utilizes the full sequence of limit order book/quote data to infer whether the position of the specialist's quotes reveals anything about future prices. The test involves a trading strategy based solely on the position of the specialist's quotes relative to the limit order book. The interpretations of the quote positions are as follows. Under the information hypothesis, if a specialist reflects only the sellside of the limit order book, he is unwilling to sell shares but is willing to buy shares, his quote position reveals the stock is undervalued. Similarly, if a specialist reflects only the buy side of the limit order book, he is unwilling to

buy shares but is willing to sell shares, his quote position reveals the stock is overvalued.

In the spirit of Handa and Schwartz (1996) the test involves placing hypothetical orders according to the specified trading strategy, assuming the orders leave the trading environment unchanged, and maintaining the portfolio until it is liquidated. Specifically, the strategy entails checking the position of the specialist's quotes relative to the book each half-hour throughout the day. If the specialist has reflected only the sellside of the book for the past three consecutive half-hour periods, buy 100 shares, if the specialist has reflected the buy side of the book for the past three consecutive half-hour periods, sell 100 shares, otherwise maintain the current inventory position. Furthermore, if the current inventory position is positive and the strategy calls for a 100 share sale, sell the current inventory position in addition to selling the 100 shares. Likewise, if the current inventory position is negative and the strategy calls for a 100 share purchase, purchase enough shares to cover the current inventory deficit in addition to the 100 share purchase. Given that the only information the strategy utilizes is the position of the specialist's quotes relative to the book, if the strategy is profitable it implies the specialist has information about the direction of future prices.

Admittedly, this strategy can not be implemented in practice. First, it assumes that the trades made by this strategy do not affect prices or depths. Second, the specialist would need to reveal the position of his quotes relative to the limit order book each half-hour. Third, there are no constraints on short-selling. Fourth, both the discount rate and borrowing rate are zero percent. It should be stressed however, that the purpose of this strategy is not to provide a profitable real-world trading strategy, rather, the purpose is to test whether the position of the specialist's quotes reveals anything about future prices.

The top panel of Table 9 summarizes the results from the posited trading strategy where trades are crossed with the specialist's quotes and the limit order book. In this panel, purchases (sales) are crossed with specialist's ask (bid) for quantities up to and including the ask (bid) depth and the limit order book for any quantities greater than the ask (bid) depth. The table presents information on the number of trades, the shares traded, the average and median profit per share, the average and median total profit and

the number of profitable stocks in each decile. The results show overwhelmingly that the strategy is unprofitable. For each decile both the median profit per share and total profit are negative. For only twenty-two percent of the stocks in the sample was this a profitable strategy; however, notice that the median loss per share is approximately the size of the bid-ask spread for each of the deciles. By having the strategy buy at the ask and sell at the bid, it implicitly builds the loss associated with the bid-ask spread into the results. The lower panel performs the trading strategy again using the same trading rules except this time it executes all transactions at the bid-ask spread midpoint in order to eliminate the cost of the bid-ask spread. The results in the lower panel are dramatically different from the upper panel. With the exception of deciles one and four, the average and median profits, whether measured on a per share basis or in total, are positive. The full sample results show a median (mean) per share profit of approximately a sixteenth, \$0.05, (\$0.04) and a median (mean) profit over the three month period of \$800 (\$1,651). Although the mean per share profit is not significantly different from zero, the mean total profit is significantly different from zero at the 0.1% level.²⁰ Moreover, two-thirds of the sample (94 stocks) post a profitable strategy. Contrary to the upper panel, the results of the lower panel provide strong evidence in favor of the information hypothesis. The results demonstrate that the position of the specialist's quotes relative to the limit order book is informative about the direction of the bid-ask spread midpoint and since the specialist is setting the quotes, *he* must have some information about the direction of the bid-ask spread midpoint.

In summary, this section reveals that the use of depth as a strategic variable is a widespread phenomenon. Specialists use depths to compete with the limit order book and Non-NYSE trading venues. Furthermore, specialists position their quotes to reflect the interest in the limit order book in order to avoid being the counter party to incoming trades. The investigation into the rationale for the specialist's actions provides evidence consistent with *both* the inventory management hypothesis and the

²⁰Even though the mean per share profit is insignificantly different from zero, it is also insignificantly different from a sixteenth or \$0.0625.

information hypothesis.

IV Statistical Tests of Depth Contribution at Information Events

The posited hypothesis is that liquidity providers, specialists in particular, reduce their contribution to depth in order to minimize the costs of trading with market participants who possess more information. This is not the first time researchers have investigated this aspect of liquidity provision. Lee, Mucklow and Ready (1993) investigate changes in price schedules surrounding earnings announcements and Foster and Viswanathan (1994) and Jennings (1994) investigate changes in price schedules surrounding takeover announcements. The empirical work in this paper is most closely related to the Lee, Mucklow and Ready (1993) paper because they also study how depths and prices interact as well as the role quoted depth plays in determining overall liquidity. They show that liquidity providers tend to coordinate prices and quantities; large spreads being associated with narrow depths; therefore it is necessary to consider both prices and depths in order to assess overall liquidity. In addition, their test of quoted depth reveals that liquidity providers anticipate adverse selection problems by widening spreads and narrowing depths prior to earnings announcements.

This work builds upon the work of Lee, Mucklow and Ready (1993) in a number of ways. First, they are unable to distinguish between depth on the limit order book and depth provided by the specialist. Their results speak to aggregate liquidity provided, while the work done here can determine who is providing the liquidity and when. Second, their measure of depth is the sum of the bid depth and the ask depth; therefore, even though their results suggest that aggregate depth falls, their work does not allow an individual analysis of each side of the market. Moreover, since earlier evidence shows that the specialist may be informed about the direction of the stock price, testing the theory on both the bid and the ask side uniformly may provide misleading results. The real question is whether the liquidity provider (specialist) uses depths to protect himself *where he thinks there is a chance of informed trading*. In the case of the earnings announcements, if the announcement is bad news, the test examines whether the liquidity

provider's bid depth is small and if the announcement is good news, the test examines whether the liquidity provider's ask depth is small. The opposite side of the market may or may not have low depth depending on whether the liquidity provider is privy to any information about the announcement. Lastly, the test is expanded to include other information events besides earnings announcements; specifically, monetary policy announcements made by the Federal Reserve's Federal Open Market Committee (FOMC) are considered. Fortunately, over the timespan of the TORQ sample the FOMC eased monetary policy by lowering the federal funds rate twenty-five basis points on four separate occasions. The specific timetable is shown in Table 10.

The empirical test is an event study around the relevant information event, either earnings announcement or FOMC announcement. Of the 144 stocks in the TORQ database, eighty-eight have earnings announcements within the sample period and eighty-three make up the final sample used in the event study whereas 143 of the stocks are included in the FOMC announcement tests.²¹ As with all event studies, it is imperative that the exact date and time of the event is known. In the case of the earnings announcements, the dates and times were obtained from the Dow Jones News Service Broadtape. The Broadtape provides the reported earnings figures prior to any subsequent corrections as well as the announcement date and time to the nearest minute. The timing for each of the FOMC announcements is 11:35AM EST. The reason for the similarity in the timing of the FOMC announcements is that during this time period, monetary policy changes and more specifically changes in the desired Federal Funds rate were signaled to the market through daily open market operations rather than direct public announcement. These operations are conducted each day between 11:30 AM and 11:35 AM EST.

In addition to determining the timing, earnings announcements must be classified as either 'good'

²¹There are various reasons for eliminating stocks. I am unable to determine the exact time of the announcement for one of the stocks. Two stocks, having their announcement on either November 1, 1990 or January 31, 1991, have insufficient observations before or after the announcement to properly perform the test. The remaining two stocks are eliminated because the firms preempted the official announcement with a preliminary announcement.

or 'bad' relative to the market's expectation in order to test the appropriate side of the market. The latest Valueline forecast is used as the proxy for the market's expectations. Earnings announcements are classified by whether the actual earnings announcement is above or below the latest Valueline forecast. Not all of the announcements in the sample are followed by Valueline; in these instances the announcement is compared to the respective earnings figure one year earlier.²² Of the eighty-three announcements forty-eight are categorized as 'bad' and thirty-five are categorized as 'good' announcements.

The statistical test involves using an estimate of the empirical distribution to test if the depth contribution around the announcement is small relative to the sample points making up the distribution. The advantage of bootstrapping the empirical distribution is that it is free from the potential for error due to an incorrect distributional assumption. However, a key assumption is that the observations of depth contributions are independent across time. The test is performed as follows. For each stock, the empirical distribution of the specialist's depth contribution, the limit order book's depth contribution and the quoted depth is constructed on each side of the market separately. Each of the six distributions is made up of 1,000 sample points. Each sample point is an average of fourteen random observations chosen from the relevant depth sequence. After constructing the six empirical distributions, the depth contribution around each announcement is calculated. For each announcement, a pre-announcement and a post-announcement observation is calculated. The pre-announcement observation is the average of the depth contribution during the day immediately preceding the announcement (fourteen observations), analogously, the post-announcement observation is the average of the depth contribution over the day immediately following the announcement (fourteen observations). Lastly, each announcement period observation (pre- and post-) for each of the six depth sequences (specialist, limit order book and quoted depth) is compared to its respective empirical distribution. For each announcement observation the

²²Of the eighty-three stocks, there was no Valueline forecast available for seventeen (20%) of them.

probability of drawing a sample point that is lower than the announcement observation (p-value) is reported.

IV.1 Results

The test results are displayed in Tables 11-15. Each of the tables report the results for the specialist, limit order book and posted quotes for both the pre-announcement period (upper panel) and the post-announcement period (lower panel). The columns represent the percentage of the announcements that report p-values less than or equal to the figure shown. Correspondingly, each row represents the cumulative distribution of the cross-section of announcement p-values.

Table 11 reports the results for the earnings announcement tests. Each announcement is segmented into the side of the market that goes *with* the announcement (labeled with) and the side of the market that goes *against* the announcement (labeled against). For example, if the announcement is a 'good' announcement in the sense that it exceeds expectations, then the ask side (sellside) of the market is labeled 'with' and the bid side (buyside) is labeled 'against', on the other hand, if the announcement is 'bad', then the bid side (buyside) is labeled 'with' and the ask side (sellside) is labeled 'against'. This labeling procedure allows the sides of the market to be grouped by their relation to the direction of the announcement rather than by whether the orders are buy or sell orders. Given the earlier evidence that specialists may be informed about the future stock price, and therefore may only react on one side of the market, the hypothesis predicts a reduction in the depth contribution by liquidity providers on the side of the market labeled 'with'.

The reported figures provide a number of interesting results. First, a substantial number of the announcements are small compared to their respective distributions, as seen by twenty percent of the earnings announcements reporting p-values below 0.05 (see column three) and most of the cumulative distribution skewed to the left. Moreover, this result holds across all liquidity providers as well as for

both pre- and post- announcement periods. Second, there are also a substantial number of announcements reporting depth contributions in the top ten percent of their respective distributions (see column ten). Third, there seems to be more of a reduction in depth contribution by the specialist before the announcement and more of a reduction in depth contribution by the limit order book after the announcement. For example, looking at column four (30%), there is a marked increase in the thirty percent cut-off for the specialist and a marked reduction in the thirty percent cut-off for the limit order book after the announcement. Lastly, the specialist reduces his depth slightly more in the direction of the announcement than against the announcement providing some support for the notion that the specialist may have some knowledge of future stock prices. These results are consistent with those reported by Lee, Mucklow and Ready (1993) as well as Foster and Viswanathan (1994) and Jennings (1994) who find low quoted depth prior to takeover announcements and a marked increase in quoted depth after takeover announcements.

In summary, the results provide evidence for the posited hypothesis in that both the specialist and the limit order book reduce their respective contributions to depth around the time of an earnings announcement. Moreover, the specialist shows more of a reduction prior to the announcement and the limit order book shows more of a reduction after the announcement, a result that is consistent with the specialist allowing the limit order book to take the brunt of any informed trading ahead of the announcement.

The other information events that are tested are FOMC announcements concerning the desired Federal Funds rate. These FOMC announcements are an interesting compliment to the earnings announcements because interest rate changes, unlike earnings announcements, allow an analysis of the effects of volatility without the confounding effects of asymmetric information. Another item of note, is that the announcements on November 14, 1990 and December 19, 1990 follow scheduled FOMC meetings whereas the announcements on December 7, 1990 and January 9, 1991 do not. This difference

suggests that the announcements on November 14, 1990 and December 19, 1990 could have been anticipated, or at least heightened the possibility of an announcement while the other two announcements would likely have been more of a surprise.

The results for each of the four FOMC announcements are reported in Tables 12-15 respectively. Contrary to the previous table, Tables 12-15 segment the results into bid and ask sides. These results are similar to the earnings announcement results in that there are substantial numbers of very small and very large depth contributions over each of the four announcement days. Although the announcements following scheduled FOMC meetings display some reduction in contributed depth, they are broadly in line with the unconditional distribution. This result is consistent with the market fully anticipating the easing move by the FOMC and already having built its effect into expectations. In contrast, the FOMC easings done on December 7, 1990 and January 9, 1991 show marked reductions in contributed depth across all liquidity providers, particularly for the specialist on the ask side of the market and the limit order book on the bid side of the market. The results demonstrate that in addition to managing depths to mitigate adverse selection problems, liquidity providers also manage depths to minimize the uncertainty associated with volatility trading periods.

Admittedly, the statistical results are clouded by some inherent difficulties associated with this test that are unavoidable. First, the test focuses on two uses specialists may have for depth, namely, reducing adverse selection costs or reducing the uncertainty associated with periods of volatile trading. There are, however, other uses specialists may have for depths which are not accounted for. For instance, the specialist may use quoted depth to manage inventory or promote price discovery. These effects, if counter to reducing adverse selection costs or reducing volatility costs, would tend to mask the significance of these results. Unfortunately, controlling for these effects is not possible due to a lack of data. Second, orders not placed through one of the automated routing systems are missing from the limit order book estimates. This may cause a misestimation (overstatement) of the depth that the specialist is

providing. For example, suppose a limit order is brought to the trading post by a floor broker for 10,000 shares at nine and the order happens to be the best limit order on the ask side of the limit order book. This order is not included in the data because it was not submitted through one of the automated routing systems. If the specialist is posting an ask of nine and an ask depth of 10,000 shares then in reality the specialist is supplying no depth. However, since the limit order book estimates lack the information on this order, the specialist would be credited with supplying a depth of 10,000 shares. This may be one reason some of the announcement observations are unusually large relative to the unconditional distribution. Even with the associated problems with the test and the data, the results still present strong evidence for the hypothesis that liquidity providers reduce contributed depth prior to an information event in order to reduce adverse selection costs or reduce the costs associated with volatile trading periods.

V Conclusion

This paper provides new insights into a number of different areas in the market micro structure field and paves the way for more research to be done. First, this work demonstrates that depths are used as a strategic choice variable by the specialist. More specifically, by lowering the depth quotes to reflect only the interest in the limit order book, the specialist can pass off unwanted trades onto the limit order book. Furthermore, evidence is presented that supports both inventory concerns as well as adverse selection/information concerns as the catalyst behind the specialist's actions. Finally, the statistical tests show that liquidity providers reduce their contribution to depth around the time of an information event whether it is to reduce adverse selection costs as with the earnings announcements, or reduce the costs associated with volatility as with the FOMC announcements.

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Table 1
Listing of TORQ Stocks
(partitioned into deciles based on average daily trading volume)

Symbol	Trade Vol Ranking	Firm Name	Year-end Price	Mkt-Cap Ranking	Earnings Announcements Date	Earnings Announcements Time
AL	1	Alcan Aluminum Limited Holding Co.	19.38	2	01/18/91	12:55 PM
AMD	1	Advanced Micro Devices Incorporated	4.81	5	01/15/91	9:41 AM
BA	1	Boeing Company	45.56	1	01/28/91	1:10 PM
CMY	1	Community Psychiatric Centers	29.13	3	11/29/90	11:47 AM
DI	1	Dresser Industries Incorporated	20.81	2	12/20/90	11:07 AM
FNM	1	Federal National Mortgage Association	35.31	1	01/15/91	10:01 AM
FPL	1	FPL Group Incorporated	29.06	2	n.a.	n.a.
GE	1	General Electric Company	57.44	1	01/22/91	2:03 PM
GLX	1	Glaxo Holdings P.L.C. ADR	32.81	1	n.a.	n.a.
HAN	1	Hanson P.L.C. ADR	18.56	1	12/06/90	9:04 AM
IBM	1	International Business Machines Corporation	112.94	1	01/17/91	8:19 AM
MO	1	Philip Morris Companies Incorporated	51.69	1	01/30/91	10:02 AM
SLB	1	Schlumberger Ltd.	57.50	1	n.a.	n.a.
T	1	American Telephone and Telegraph Company	30.19	1	01/24/91	9:04 AM
XON	1	Exxon Corporation	51.75	1	01/24/91	12:59 PM
ACN	2	Acuson Corporation	26.69	3	n.a.	n.a.
CAL	2	Calfed Incorporated	4.25	7	01/24/91	8:34 AM
CL	2	Colgate-Palmolive Company	73.63	1	n.a.	n.a.
CLE	2	Claire's Stores Incorporated	9.69	6	11/19/90	11:06 AM
CP	2	Canadian Pacific Limited	16.94	2	11/05/90	10:01 AM
CPC	2	CPC International Incorporated	83.38	1	n.a.	n.a.
EMC	2	EMC Corporation	7.94	6	n.a.	n.a.
FBO	2	Federal Paper Board Company Incorporated	18.38	4	01/25/91	8:44 AM
FDX	2	Federal Express Corporation	33.94	2	12/20/90	4:57 PM
KR	2	Kroger Company	14.13	3	n.a.	n.a.
NT	2	Northern Telecom Ltd.	27.94	1	01/22/91	9:17 AM
PCO	2	Pittston Company	18.94	4	01/25/91	9:00 AM
POM	2	Potomac Electric Power Company	20.63	2	01/24/91	3:37 PM
SNT	2	Sonat Incorporated	46.69	2	01/23/91	11:41 AM
WBN	2	Waban Incorporated	11.06	5	11/13/90	11:05 AM

Table 1 (continued)
Listing of TORQ Stocks
(partitioned into deciles based on average daily trading volume)

Symbol	Trade Vol Ranking	Firm Name	Year-end Price	Mkt-Cap Ranking	Earnings Date	Announcements Time
CUE	3	Quantum Chemical Corporation	12.25	5	01/31/91	9:52 AM
CYM	3	Cyprus Minerals Company	18.56	4	n.a.	n.a.
CYR	3	Cray Research Incorporated	30.13	3	01/23/91	5:40 PM
FFB	3	First Fidelity Bancorporation	17.50	3	01/17/91	12:17 PM
FOE	3	Ferro Corporation	18.06	5	01/25/91	5:26 PM
LPX	3	Louisiana-Pacific Corporation	27.38	3	01/22/91	9:04 AM
NI	3	NipSCO Industries Incorporated Holding Company	18.88	3	n.a.	n.a.
NSP	3	Northern States Power Company Minnesota	33.88	2	01/23/91	4:05 PM
PH	3	Parker-Hannifin Corporation	23.88	3	01/17/91	9:15 AM
PRI	3	Promus Companies Incorporated	14.75	4	n.a.	n.a.
RDA	3	Readers Digest Association Incorporated	29.44	2	n.a.	n.a.
TEK	3	Tektronix Incorporated	18.50	4	11/29/90	4:04 PM
UEP	3	Union Electric Company	29.75	2	n.a.	n.a.
VRC	3	Varco International Incorporated	8.50	6	11/02/90	10:42 AM
W	3	Westvaco Corporation	26.63	2	11/15/90	1:24 PM
AMO	4	Allstate Municipal Income Opportunities Trust	8.81	6	n.a.	n.a.
AR	4	Asarco Incorporated	27.13	3	01/30/91	9:21 AM
CMH	4	Clayton Homes Incorporated	13.63	4	01/14/91	9:33 AM
CU	4	CUC International Incorporated	22.19	3	11/29/90	11:47 AM
DCN	4	Dana Corporation	29.75	3	n.a.	n.a.
FPC	4	Florida Progress Corporation	38.31	2	01/31/91	3:07 PM
HTR	4	Hyperion Total Return Fund Incorporated	10.19	6	n.a.	n.a.
MON	4	Monarch Capital Corporation	0.53	10	11/15/90	10:12 AM
NSI	4	National Service Industries Incorporated	25.25	3	12/19/90	2:06 PM
PIM	4	Putnam Master Intermediate Income Trust	6.69	6	n.a.	n.a.
PIR	4	Pier 1 Imports Incorporated	4.88	6	12/19/90	9:33 AM
PMI	4	Premark International Incorporated	17.31	4	01/29/91	11:09 AM
PPL	4	Pennsylvania Power Light Company	43.69	2	01/23/91	1:46 PM
SPF	4	Standard Pacific L.F. Dep. RCPTS	5.88	7	01/23/91	3:43 PM
SWY	4	Safeway Incorporated	12.25	3	n.a.	n.a.

Table 1 (continued)
 Listing of TORQ Stocks
 (partitioned into deciles based on average daily trading volume)

Symbol	Trade Vol Ranking	Firm Name	Year-end Price	Mkt-Cap Ranking	Earnings Announcements Date	Earnings Announcements Time
ADU	5	Amdura Corporation	0.09	10	12/11/90	3:18 PM
ATE	5	Atlantic Energy Incorporated	33.81	3	n.a.	n.a.
BG	5	Brown Group Incorporated	22.06	5	11/28/90	11:07 AM
BZF	5	Brazil Fund Incorporated	6.69	7	n.a.	n.a.
DBD	5	Diebold Incorporated	34.81	4	01/17/91	12:56 PM
HE	5	Hawaiian Electric Industries Incorporated	31.56	4	n.a.	n.a.
HF	5	House of Fabrics Incorporated	30.25	4	11/27/90	8:58 AM
ITG	5	Integra-A Hotel and Restaurant Company	0.08	10	11/19/90	5:16 PM
KFV	5	Quest for Value Dual Purpose Fund Incorporated	11.94	6	n.a.	n.a.
KWD	5	Kellwood Company	11.25	7	11/27/90	1:14 PM
MX	5	Measurex Corporation	18.13	5	12/19/90	8:54 AM
USH	5	Uslife Corporation	28.06	5	n.a.	n.a.
WCS	5	Wallace Computer Services Incorporated	20.06	4	12/04/90	9:58 AM
WIN	5	Winn-Dixie Stores Incorporated	32.00	2	01/23/91	2:04 PM
AC	6	Alliance Capital Management L.P. Units	16.75	4	01/30/91	12:37 PM
BMC	6	BMC Industries Incorporated	3.88	9	n.a.	n.a.
CLF	6	Cleveland Cliffs Incorporated	27.19	5	01/25/91	12:37 PM
CPY	6	CPI Corporation	27.81	5	12/13/90	11:53 AM
DSI	6	Dreyfus Strategic Governments Income Incorporated	10.75	7	n.a.	n.a.
GBE	6	Grubb and Ellis Company	1.19	9	11/09/90	9:27 AM
MCN	6	MCN Corporation Holding Company	21.44	4	11/05/90	3:55 PM
MDP	6	Meredith Corporation	23.81	5	n.a.	n.a.
MRT	6	Mortgage Realty Trust	2.44	9	11/20/90	1:20 PM
PLP	6	Plains Petroleum Company	26.06	6	n.a.	n.a.
RPS	6	RPS Realty Trust S.B.I.	5.44	7	11/14/90	10:35 AM
TXI	6	Texas Industries Incorporated	15.44	7	12/20/90	3:51 PM
UAM	6	United Asset Management Corporation	16.19	6	n.a.	n.a.
ZNT	6	Zenith National Insurance Corporation	13.50	6	n.a.	n.a.

Table 1 (continued)
Listing of TORQ Stocks

(partitioned into deciles based on average daily trading volume)

Symbol	Trade Vol Ranking	Firm Name	Year-end Price	Mkt-Cap Ranking	Earnings Date	Announcements Time
ALL	7	Allstate Municipal Income Trust III S.B.I.	8.81	8	n.a.	n.a.
BRT	7	BRT Realty Trust S.B.I.	2.31	9	11/26/90	4:38 PM
DP	7	Diagnostic Products Corporation	33.50	5	n.a.	n.a.
EKO	7	EKCO Group Incorporated	2.69	9	n.a.	n.a.
FLP	7	Floating Point Systems Incorporated	1.06	10	01/03/91	11:16 AM
GMH	7	General Motors Corporation Class H	17.69	2	n.a.	n.a.
HFI	7	Hudson Foods Inc. Class A Common	7.69	8	01/22/91	8:38 AM
ICM	7	ICM Property Investors Incorporated	3.56	9	n.a.	n.a.
IPT	7	IP Timberlands Ltd. Class A Dep. Units	17.69	3	01/09/91	9:52 AM
NIC	7	Nicolet Instrument Corporation	7.81	8	01/29/91	4:45 PM
OCQ	7	Oneida Ltd.	9.13	7	11/28/90	10:48 AM
SAH	7	Sahara Casino Partners L.P. Dep Units	5.06	7	12/24/90	11:57 AM
TUG	7	Maritans Partners L.P. Dep. RCPTS	6.50	7	01/29/91	5:55 PM
UWR	7	United Water Resources Incorporated	11.25	6	01/28/91	9:14 AM
ARX	8	ARX Incorporated	1.44	9	11/14/90	5:28 PM
AYD	8	Aydin Corporation	13.31	8	n.a.	n.a.
CMI	8	Club Med Incorporated	21.50	5	01/28/91	4:19 PM
COA	8	Coachman Industries Incorporated	3.69	9	11/07/90	3:06 PM
FMI	8	Franklin Multi-Income Trust S.B.I.	7.13	9	n.a.	n.a.
IEI	8	Indiana Energy Incorporated	23.25	5	n.a.	n.a.
IS	8	Interstate/Johnson Lane Incorporated	2.31	9	n.a.	n.a.
LOG	8	Rayonier Timberlands L.P. Class A Dep. Units	18.63	5	n.a.	n.a.
MNY	8	Taurus Muni New York Holdings Incorporated	10.38	8	n.a.	n.a.
NNP	8	Nuveen New York Performance plus Muni Fund	14.75	7	n.a.	n.a.
REC	8	Recognition Equipment Incorporated	5.13	8	12/11/90	9:26 AM
UMG	8	Universal Matchbox Group Ltd.	1.75	9	n.a.	n.a.
WHX	8	Wheeling-Pittsburgh Steel Corporation	3.75	8	n.a.	n.a.
ZIF	8	Zenix Income Fund Incorporated	4.81	8	n.a.	n.a.

Table 1 (continued)

Listing of TORQ Stocks

(partitioned into deciles based on average daily trading volume)

Symbol	Trade Vol Ranking	Firm Name	Year-end Price	Mkt-Cap Ranking	Earnings Announcements Date	Time
ALX	9	Alexanders Incorporated	22.81	7	12/04/90	3:33 PM
CUC	9	Culbro Corporation	15.50	8	11/12/90	2:54 PM
DLT	9	Deltona Corporation	0.48	10	11/06/90	5:52 PM
EFG	9	Equitec Financial Group Incorporated	0.04	10	n.a.	n.a.
EHP	9	Emerald Homes L.P. Dep. RCPTS	0.28	10	n.a.	n.a.
GPI	9	Guardsman Products Incorporated	9.00	8	01/25/91	3:02 PM
GRH	9	GRC International Incorporated	2.50	9	11/05/90	10:54 AM
LUK	9	Leucadia National Corporation	22.63	6	11/14/90	9:09 AM
NSO	9	New American Shoe Company Incorporated	0.04	10	n.a.	n.a.
PEO	9	Petroleum Resources Corporation	25.19	6	n.a.	n.a.
SJI	9	South Jersey Industries Incorporated	18.56	7	n.a.	n.a.
UTD	9	United Investors Management Company	15.88	4	n.a.	n.a.
WAE	9	Wilfred American Educational Corporation	0.05	10	n.a.	n.a.
WDG	9	Wedgestone Financial S.B.I.	0.56	10	11/16/90	12:51 PM
ACS	10	American Capital Convertible Securities Incorporated	16.50	8	n.a.	n.a.
AMN	10	Ameron Incorporated	38.31	7	01/25/91	5:14 PM
GFB	10	GF Corporation	n.a.	10	n.a.	n.a.
HAT	10	Halteras Income Securities Incorporated	14.69	8	n.a.	n.a.
MBK	10	Mitsubishi Bank Limited ADR	15.63	1	n.a.	n.a.
MC	10	Matsushita Electric Industrial Company Ltd. ADR	117.69	1	11/16/90	7:52 AM
MCC	10	Mesta Machine Company	7.75	8	11/08/90	1:00 PM
MTR	10	Mesa Royalty Trust U.B.I.	41.25	8	n.a.	n.a.
OEH	10	Orient Express Hotels Incorporated	3.25	9	11/15/90	6:28 PM
SLT	10	Salant Corporation	1.63	10	n.a.	n.a.
TCI	10	Transcontinental Realty Investors S.B.I.	4.13	10	11/14/90	1:50 PM
URS	10	URS Corporation	3.19	9	12/20/90	1:59 PM
VCC	10	Volunteer Capital Corporation	1.31	10	n.a.	n.a.
Y	10	Alleghany Corporation	85.38	4	n.a.	n.a.

Table 2
Average Percentage of Discarded Records by Type
 (expressed in percentage points)

	Total Records	Executions	Cancellations	Other	Total
Large	28,084	0.05	0.36	0.15	0.56
2	6,188	0.01	0.34	0.15	0.51
3	3,910	0.01	0.31	0.21	0.53
4	3,079	0.04	0.29	0.18	0.51
5	1,589	0.02	0.35	0.25	0.63
6	1,606	0.01	0.35	0.08	0.43
7	1,274	0.05	0.29	0.09	0.42
8	946	0.01	0.30	0.13	0.44
9	508	0.08	0.20	0.42	0.70
Small	374	0.01	0.31	0.42	0.75

Analysis by Individual Stock	
Median	1,766
Maximum	56,940
	0.00
	0.92
	0.29
	1.23
	0.10
	4.17
	0.48
	4.17

- Notes:
- (1) Data are calculated for each stock as of January 31, 1991 at 4:00 PM.
 - (2) Figures are expressed as a percentage of the total number of records for that stock, and are then averaged across stocks within their respective decile, with each stock receiving equal weight.
 - (3) Executions and cancellations represent execution and cancellation records respectively, as a percentage of the total records, that were not matched to an order record.
 - (4) The other category represents records that were eliminated because their inclusion would violate some basic premise of the limit order book. Examples include buy (sell) orders above (below) the ask (bid) or limit orders with no limit price.

Table 3
The Limit Order Book for Federal Express (FDX) on November 21, 1990 at 12:00

Date	Time	Side	Type	Shares	Price						
900405	n.a.	SEL	GTC	800	65.000						
900419	n.a.	SEL	GTC	100	59.000						
900522	n.a.	SEL	GTC	250	55.000						
900820	n.a.	SEL	GTC	200	53.250						
901120	142851	SEL	GTC	200	50.000						
900628	n.a.	SEL	GTC	200	50.000						
900618	n.a.	SST	GTC	900	49.875						
900801	n.a.	SEL	GTC	100	46.500						
900906	n.a.	SEL	GTC	200	44.000						
900906	n.a.	SEL	GTC	200	44.000						
901025	n.a.	SEL	GTC	100	40.875						
901024	n.a.	SEL	GTC	300	40.500						
901106	153708	SEL	GTC	800	40.000						
901025	n.a.	SEL	GTC	100	39.875						
901026	n.a.	SEL	GTC	200	39.500						
901030	n.a.	SEL	GTC	100	37.500						
901106	153628	SEL	GTC	500	36.000						
901121	92225	SST	GTC	200	34.000						
901120	150751	SEL	GTC	100	34.000						
901121	114107	SST	DAY	200	33.500						
901120	130034	SST	GTC	1,000	33.500						
901121	101944	SST	DAY	300	33.000						
901121	93017	SST	DAY	1,000	32.875						
901121	110431	SEL	DAY	500	32.500						
901121	112803	SEL	DAY	100	32.375						
901121	110459	SEL	DAY	2,000	32.375						
NYSE Specialist Quote				2,000	32.375	32.125	5,000				
Best Non-NYSE Quote				Cincinnati	500	32.500	32.000	500	Cincinnati		
Notes:						32.125	1,100	DAY	BUY	114647	901121
						32.000	800	DAY	BUY	112153	901121
(1) Date and Time refer to the date and time the order was submitted. Times are unavailable prior to 901101.						30.875	500	GTC	BUY	85038	901121
(2) Side specifies the side of the market: SEL=regular sale, SST=short-sale, BUY=regular buy.						30.000	200	GTC	BUY	n.a.	900821
						30.000	100	GTC	BUY	n.a.	900823
(3) Type provides the duration. GTC and DAY stand for Good-until-canceled and Day limit order respectively.						30.000	100	GTC	BUY	n.a.	900823
						30.000	500	GTC	BUY	n.a.	900925
(4) The NYSE and Non-NYSE quotes display the ask depth, ask, bid, and bid depth respectively.						29.875	100	GTC	BUY	n.a.	901026
						28.000	100	GTC	BUY	n.a.	900821
						17.750	200	GTC	BUY	n.a.	900820
						Price	Shares	Type	Side	Time	Date

Table 4
Volume on the Limit Order Book

	Buyside					Sellside						
	Number of Orders	Order Size	Total Volume	Tot Vol as % of ADV	Volume at Best Bid	% Volume at Best Bid	Number of Orders	Order Size	Total Volume	Tot Vol as % of ADV	Volume at Best Ask	% Volume at Best Bid
Large	413	870	211,461	25.13	10,006	8.91	160	1,409	144,911	21.62	11,119	9.90
2	52	1,132	67,893	52.10	4,254	14.95	33	1,268	38,659	28.48	4,849	15.22
3	25	1,254	28,664	32.12	3,485	15.97	20	1,235	22,867	25.94	3,893	19.27
4	27	2,458	83,898	180.91	15,382	19.08	21	2,356	61,471	130.69	13,454	25.84
5	22	1,927	31,858	115.81	6,775	26.70	8	2,151	19,129	69.60	3,874	30.35
6	17	2,036	39,481	210.27	8,037	26.09	10	2,438	26,153	138.20	5,731	35.65
7	19	1,602	27,612	228.73	4,897	19.96	5	1,310	18,238	150.54	4,155	28.11
8	13	1,551	18,978	241.71	3,719	24.16	11	1,468	16,335	206.70	3,394	24.32
9	7	2,796	12,531	268.87	5,886	46.72	8	1,618	10,948	226.91	3,187	40.71
Small	4	1,620	7,230	371.82	2,665	49.58	4	1,279	7,429	1976.50	1,557	49.63
Total	62	1,716	54,211	168.55	6,560	24.75	30	1,651	37,457	280.68	5,599	27.61

Notes: (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
(2) Order size is equal to the total volume divided by the number of orders.
(3) ADV stands for Average Daily trading Volume.

Table 5

Spreads on the Limit Order Book

	Buyside		Limit Order Book		Specialist Quote		Sellside	
	Dollar Dispersion	Percentage Dispersion	Dollar Spread	Percentage Spread	Dollar Spread	Percentage Spread	Dollar Dispersion	Percentage Dispersion
Large	-3.66	-8.86	0.24	0.90	0.17	0.69	2.82	9.04
2	-2.39	-11.51	0.49	2.40	0.20	1.29	2.11	11.34
3	-2.65	-13.06	0.54	2.79	0.22	1.15	2.26	12.81
4	-1.62	-10.44	0.57	3.99	0.20	2.09	1.47	19.23
5	-1.48	-10.75	0.95	10.95	0.22	6.12	1.26	38.70
6	-0.80	-8.34	0.97	6.80	0.24	2.93	1.57	23.15
7	-0.80	-8.52	0.49	5.93	0.22	3.89	1.40	18.63
8	-0.69	-8.52	0.43	7.03	0.22	4.16	1.41	28.00
9	-0.30	-9.54	0.82	28.93	0.20	12.89	1.29	73.65
Small	-0.69	-5.04	2.00	11.69	0.38	5.24	0.87	14.25
Total	-1.55	-9.53	0.73	7.96	0.23	3.96	1.66	24.63

Notes:

- (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
- (2) Dollar dispersion is the dollar difference between the best price on the limit order book and the volume weighted price for that subgroup.
- (3) Percentage dispersion is the dollar dispersion divided by the limit order book's bid-ask midpoint.
- (4) The limit order book dollar spread is the difference between the best ask and best bid on the limit order book.
- (5) Percentage spread is the dollar spread divided by the limit order book's bid-ask midpoint.

Table 6
Percent Participation by the NYSE Specialist and Average Depth by Provider

	Byside					Sellside						
	Hidden Orders	No Spec. Depth	Specialist Depth	Specialist Alone	LOB Depth	Specialist Depth	No Spec. Depth	Specialist Depth	Specialist Alone	LOB Depth	Specialist Depth	
Large	7.06	16.47	52.75	23.72	8,155	11,238	8.55	15.19	54.58	21.68	9,167	13,457
2	7.15	20.95	34.44	37.46	3,170	4,671	7.05	19.12	37.70	36.13	3,193	5,799
3	5.30	18.35	30.26	46.09	1,847	3,393	8.64	21.40	32.27	37.69	2,370	4,303
4	8.37	29.47	26.59	35.57	14,095	2,089	5.20	34.43	29.17	31.19	11,777	2,657
5	12.99	20.32	22.46	44.24	4,097	2,079	8.67	21.94	19.71	49.68	2,144	1,982
6	6.34	33.66	24.28	35.72	6,852	1,031	5.90	34.50	20.39	39.21	4,302	1,264
7	9.31	40.37	26.46	23.86	4,166	637	4.39	37.98	21.58	36.50	3,141	746
8	9.89	40.99	21.95	27.16	2,985	588	8.09	41.03	18.68	32.20	2,380	575
9	16.47	26.90	13.03	43.59	2,132	1,837	8.71	27.27	11.56	52.47	940	1,257
Small	5.37	45.34	15.84	33.45	2,036	354	14.16	30.58	16.52	38.74	874	389
Total	8.76	28.61	27.60	35.02	5,005	2,863	7.77	28.15	27.10	36.98	4,101	3,335

- Notes:
- (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
 - (2) Hidden orders refer to cases where the specialist is posting an inferior price relative to the best limit order on the book.
 - (3) No Spec. Depth (Specialist Depth) refers to instances where the specialist's posted price matches the price of the best limit order and the posted depth quote is equal to or less than (greater than) the volume at that best limit order price.
 - (4) Specialist Alone reflects cases where the specialist posts a better price than the best limit order on the book.
 - (5) The sum of columns 1 through 4 (7 through 10) is 1.0.
 - (6) The sum of columns 5 and 6 (11 and 12) is the average total depth provided to the market.

Table 7
Percent Participation by the Non-NYSE Venues and Average Depth Relative to the NYSE

	Buyside					Sellside					
	NYSE Sup Price	NYSE Lg Depth	Regional Lg Depth	Regional Sup Price	Regional Depth	NYSE Sup Price	NYSE Lg Depth	Regional Lg Depth	Regional Sup Price	Regional Depth	NYSE Depth
Large	31.61	58.94	1.49	7.96	1,051	27.31	62.55	1.30	8.84	1,257	21,399
2	40.88	49.33	1.54	8.24	525	38.00	51.39	1.57	9.03	720	8,251
3	26.52	61.89	2.34	9.25	486	27.98	60.00	2.04	9.97	569	6,167
4	37.04	54.11	2.82	6.03	1,215	34.52	54.84	3.01	7.63	1,243	13,138
5	44.67	43.94	3.96	7.44	592	48.11	38.09	4.43	9.36	445	3,542
6	48.63	42.15	2.06	7.16	464	43.04	49.02	2.49	5.44	353	5,133
7	42.79	47.85	2.66	6.70	354	40.55	48.46	3.18	7.81	336	3,478
8	47.15	38.91	7.21	6.73	616	52.44	34.11	6.84	6.60	619	2,357
9	44.11	47.83	1.75	6.30	227	50.76	38.82	2.62	7.80	222	1,791
Small	37.66	55.36	4.02	2.96	158	24.98	65.86	5.21	3.95	92	1,419
Total	39.49	50.40	2.87	7.24	595	38.91	49.30	3.07	8.11	619	7,160

- Notes:
- (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
 - (2) NYSE (Regional) Sup Price refers to cases where the NYSE (Regional) is posting a superior price relative to its competitors.
 - (3) NYSE (Regional) Lg Depth refers to instances where the NYSE and regional exchanges are posting the same price and the NYSE (Regional) is posting a larger depth quote.
 - (4) The sum of columns 1 through 4 (7 through 10) is 1.0.
 - (5) The sum of columns 5 and 6 (11 and 12) is the average total depth provided to the market.

Table 8
Positioning of the Specialist's Quotes in Relation to the Limit Order Book

	Rising Prices			Falling Prices				
	Reflects Bid & Ask	Reflects Ask/Sell	Reflects Bid/Buy	Reflects Bid & Ask	Reflects Ask/Sell	Reflects Bid/Buy		
Conditioning on Prior Price Changes								
Large	7.89	18.96	10.15	63.00	7.05	11.92	24.13	56.90
2	13.60	23.94	14.77	47.69	7.31	11.58	31.79	49.32
3	7.14	30.05	12.88	49.93	6.58	14.09	21.52	57.81
4	9.77	30.94	16.91	42.37	10.91	13.31	32.77	43.01
5	12.06	20.88	15.95	51.11	4.70	18.66	19.43	57.20
6	11.04	28.79	14.47	45.69	8.07	16.03	23.93	51.97
7	26.72	17.53	20.59	35.16	3.39	14.74	49.01	32.86
8	7.92	42.62	6.46	42.99	15.00	12.78	27.16	45.06
9	2.56	35.11	26.53	35.80	1.04	10.42	21.88	66.67
Small	10.00	28.33	14.35	47.32	5.93	30.74	15.56	47.78
Total	10.87	27.72	15.31	46.11	7.00	15.43	26.72	50.86

	Rising Prices			Falling Prices				
	Reflects Bid & Ask	Reflects Ask/Sell	Reflects Bid/Buy	Reflects Bid & Ask	Reflects Ask/Sell	Reflects Bid/Buy		
Conditioning on Subsequent Price Changes								
Large	8.75	15.31	14.03	61.91	7.32	18.53	11.10	63.05
2	6.08	18.64	24.07	51.21	9.31	22.57	15.96	52.15
3	7.45	19.16	17.72	55.67	7.47	26.88	13.57	52.08
4	8.29	22.31	23.71	45.70	18.07	21.24	24.35	36.34
5	12.31	12.80	24.54	50.35	17.70	17.42	10.93	53.95
6	19.34	16.81	28.44	35.41	16.73	22.34	11.36	49.57
7	22.44	13.64	38.98	24.94	14.76	5.62	35.36	44.27
8	17.48	7.16	39.80	35.56	21.88	41.31	11.53	25.28
9	17.88	16.67	39.18	26.27	16.67	18.13	18.13	47.08
Small	18.33	15.83	8.69	57.14	17.04	23.52	2.22	57.22
Total	13.84	15.83	25.92	44.42	14.69	21.75	15.45	48.10

Notes: (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
(2) The conditioning criteria requires two consecutive increases (decreases) in both the posted bid and ask.
(3) The sum of columns 1 through 4 (5 through 8) is 1.0.

Table 9

Test of the Information Hypothesis Using a Limit Order Book Trading Strategy

	Number of Trades	Shares Traded	Ave. Profit per Share	Md. Profit per Share	Ave. Total Profit	Md. Total Profit	Profitable Stocks
Transaction Prices are the Posted Quotes and the Limit Order Book							
Large	38	7,373	0.51	-0.14	-552	-363	5
2	84	16,573	-0.41	-0.19	-2,010	-1,975	5
3	96	18,933	-0.24	-0.25	-2,126	-2,018	3
4	150	29,853	-0.17	-0.15	-2,320	-2,373	2
5	182	36,229	-1.16	-0.57	-17,367	-8,050	0
6	183	36,443	-0.64	-0.31	-11,133	-6,006	0
7	227	45,171	-0.29	-0.21	10,030	-4,338	3
8	240	47,893	-0.10	-0.25	-4,374	-6,192	2
9	292	58,236	-0.91	-0.15	-34,027	-2,960	5
Small	273	54,429	-3.54	-0.25	-128,000	-2,865	6
Total	174	34,643	-0.60	-0.24	-18,712	-3,920	31

	Number of Trades	Shares Traded	Ave. Profit per Share	Md. Profit per Share	Ave. Total Profit	Md. Total Profit	Profitable Stocks
Transaction Prices are the Posted Bid-Ask Midpoint							
Large	38	7,373	-0.63	0.03	98	81	8
2	84	16,573	0.22	0.05	457	575	8
3	96	18,933	0.02	0.07	71	644	8
4	150	29,853	-0.02	0.01	-124	431	8
5	182	36,229	0.19	0.13	2,356	1,866	11
6	183	36,443	0.09	0.05	1,361	917	9
7	227	45,171	0.05	0.04	1,308	753	10
8	240	47,893	0.09	0.06	1,840	1,309	12
9	292	58,236	0.08	0.07	2,086	1,144	9
Small	273	54,429	0.36	0.12	7,497	3,041	11
Total	174	34,643	0.04	0.05	1,651	806	94

- Notes:
- (1) Figures are averaged across time for each stock and then are averaged across stocks within their respective decile, with each stock receiving equal weight.
 - (2) The purchase (sale) condition requires that the specialist reflect the ask (bid) for the past three consecutive half-hour periods. The transaction amount is 100 shares unless there is a position liquidation.
 - (3) Ave. (Md.) per share and total profit refer to the mean (median) figures.

Table 10
Federal Reserve Monetary Policy Announcements

Date	Event	Federal Funds Rate		Discount Rate	
		Level	Change	Level	Change
11/13/90	FOMC Meeting	7.75	0.00	7.00	0.00
11/14/90	Easing Move	7.50	-0.25	7.00	0.00
12/07/90	Easing Move	7.25	-0.25	7.00	0.00
12/17&18/90	FOMC Meeting	7.25	0.00	7.00	0.00
12/19/90	Easing Move	7.00	-0.25	6.50	-0.50
01/09/91	Easing Move	6.75	-0.25	6.50	0.00

Notes: (1) FOMC Meeting refers to one of the eight scheduled meetings of the Federal Open Market Committee.
(2) Easing move refers to a reduction in the desired level of the Federal Funds rate or Discount rate. Easing moves such as these were implemented through open market operations conducted each day at 11:30 AM EST.

Table 11
Statistical Test of Depth Contribution around Earnings Announcements

Liquidity Provider	Direction	Percentage of Announcements having depth less than or equal to the figure shown									
		5%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Pre-Announcement Period											
Specialist	With	0.002	0.015	0.043	0.111	0.194	0.338	0.576	0.767	0.860	0.975
	Against	0.008	0.020	0.042	0.109	0.248	0.397	0.636	0.722	0.901	0.996
LOB	With	0.005	0.006	0.043	0.192	0.321	0.531	0.698	0.845	0.899	0.976
	Against	0.001	0.006	0.040	0.098	0.188	0.278	0.387	0.678	0.930	0.987
Quotes	With	0.004	0.011	0.083	0.284	0.442	0.564	0.631	0.722	0.866	0.984
	Against	0.004	0.009	0.063	0.093	0.249	0.405	0.483	0.651	0.942	0.999
Post-Announcement Period											
Specialist	With	0.004	0.014	0.061	0.206	0.247	0.396	0.605	0.820	0.941	0.996
	Against	0.009	0.037	0.087	0.232	0.359	0.488	0.636	0.784	0.899	0.989
LOB	With	0.005	0.010	0.043	0.080	0.189	0.405	0.541	0.791	0.915	0.998
	Against	0.004	0.009	0.025	0.064	0.126	0.206	0.450	0.695	0.872	0.926
Quotes	With	0.002	0.005	0.045	0.098	0.261	0.433	0.712	0.838	0.920	0.997
	Against	0.003	0.009	0.022	0.057	0.207	0.303	0.460	0.672	0.855	0.960

Notes: (1) Figures represent p-values. The table shows where the announcement depths fall relative to each stock's/liquidity provider's own empirical distribution. For example, looking down the 20% column, we see that 20% of the earnings announcements had pre-announcement specialist depth contributions in the lowest 4% of their respective distributions. A set of random draws would yield 20% rather than 4%.
(2) Empirical distributions are constructed for each liquidity provider within each stock by averaging 14 random draws 1000 times each.
(3) The pre- (post-) announcement period observation is the average of the 14 half-hour observations immediately prior (subsequent) to the earning announcement.
(2) Direction refers to the side of the market relative to the direction of the earnings announcement (with or against). If the announcement was good (bad) news, the ask (bid) side is labeled 'with' and the bid (ask) 'against'.

Table 12
 Statistical Test of Depth Contribution around the November 14, 1990 Federal Reserve Announcement

Liquidity Provider	Side of Market	Percentage of Announcements having depth less than or equal to the figure shown									
		5%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Pre-Announcement Period											
Specialist	Bid	0.011	0.026	0.060	0.093	0.291	0.493	0.634	0.794	0.909	0.989
	Ask	0.003	0.021	0.090	0.199	0.313	0.445	0.634	0.822	0.914	0.995
LOB	Bid	0.002	0.004	0.024	0.098	0.155	0.403	0.542	0.747	0.915	0.993
	Ask	0.002	0.011	0.024	0.134	0.268	0.424	0.600	0.798	0.864	0.975
Quotes	Bid	0.003	0.007	0.034	0.137	0.327	0.529	0.652	0.826	0.961	1.000
	Ask	0.001	0.004	0.032	0.079	0.246	0.423	0.567	0.841	0.961	0.999
Post-Announcement Period											
Specialist	Bid	0.004	0.014	0.049	0.126	0.190	0.337	0.507	0.726	0.846	0.984
	Ask	0.006	0.015	0.053	0.114	0.248	0.415	0.669	0.794	0.908	0.970
LOB	Bid	0.006	0.011	0.065	0.147	0.296	0.428	0.673	0.810	0.936	0.992
	Ask	0.005	0.015	0.053	0.105	0.272	0.434	0.595	0.708	0.919	0.997
Quotes	Bid	0.003	0.006	0.028	0.111	0.154	0.270	0.576	0.837	0.924	0.999
	Ask	0.002	0.016	0.066	0.183	0.429	0.580	0.698	0.837	0.938	0.996

Notes: (1) Figures represent p-values. The table shows where the announcement depths fall relative to each stock's/liquidity provider's own empirical distribution.
 (2) Empirical distributions are constructed for each liquidity provider within each stock by averaging 14 random draws 1000 times each.
 (3) The pre- (post-) announcement period observation is the average of the 14 half-hour observations immediately prior (subsequent) to 11:35 AM EST November 14, 1990.
 (4) The Federal Open Market Committee (FOMC) met on November 13, 1990.

Table 13

Statistical Test of Depth Contribution around the December 7, 1990 Federal Reserve Announcement

Liquidity Provider	Side of Market	Percentage of Announcements having depth less than or equal to the figure shown									
		5%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Pre-Announcement Period											
Specialist	Bid	0.016	0.023	0.078	0.167	0.266	0.460	0.634	0.824	0.957	0.996
	Ask	0.013	0.026	0.048	0.113	0.261	0.394	0.633	0.791	0.933	0.987
LOB	Bid	0.003	0.008	0.034	0.067	0.177	0.350	0.502	0.844	0.954	0.990
	Ask	0.015	0.035	0.073	0.225	0.360	0.568	0.663	0.791	0.941	0.991
Quotes	Bid	0.002	0.003	0.050	0.161	0.269	0.594	0.731	0.906	0.975	0.999
	Ask	0.007	0.012	0.088	0.161	0.380	0.506	0.690	0.912	0.991	1.000
Post-Announcement Period											
Specialist	Bid	0.003	0.015	0.053	0.173	0.307	0.489	0.591	0.809	0.899	0.987
	Ask	0.003	0.008	0.035	0.079	0.177	0.282	0.487	0.785	0.915	0.980
LOB	Bid	0.006	0.014	0.041	0.084	0.239	0.409	0.553	0.699	0.881	0.990
	Ask	0.015	0.065	0.117	0.208	0.446	0.636	0.792	0.874	0.967	0.995
Quotes	Bid	0.003	0.008	0.031	0.084	0.220	0.424	0.573	0.844	0.927	0.997
	Ask	0.003	0.011	0.058	0.166	0.320	0.523	0.680	0.873	0.977	0.999

Notes:

- (1) Figures represent p-values. The table shows where the announcement depths fall relative to each stock's/liquidity provider's own empirical distribution.
- (2) Empirical distributions are constructed for each liquidity provider within each stock by averaging 14 random draws 1000 times each.
- (3) The pre- (post-) announcement period observation is the average of the 14 half-hour observations immediately prior (subsequent) to 11:35 AM EST December 7, 1990.

Table 14

Statistical Test of Depth Contribution around the December 19, 1990 Federal Reserve Announcement

Liquidity Provider	Side of Market	Percentage of Announcements having depth less than or equal to the figure shown									
		5%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Pre-Announcement Period											
Specialist	Bid	0.008	0.013	0.082	0.177	0.355	0.554	0.742	0.865	0.952	0.988
	Ask	0.003	0.009	0.038	0.096	0.178	0.332	0.623	0.783	0.917	0.992
LOB	Bid	0.003	0.009	0.047	0.105	0.263	0.430	0.624	0.831	0.949	1.000
	Ask	0.003	0.007	0.061	0.132	0.279	0.501	0.641	0.819	0.921	0.993
Quotes	Bid	0.004	0.011	0.072	0.150	0.322	0.507	0.694	0.879	0.988	1.000
	Ask	0.003	0.007	0.052	0.119	0.208	0.536	0.716	0.853	0.952	0.998
Post-Announcement Period											
Specialist	Bid	0.011	0.025	0.073	0.183	0.356	0.522	0.703	0.844	0.917	0.986
	Ask	0.004	0.006	0.027	0.124	0.233	0.452	0.671	0.752	0.875	0.993
LOB	Bid	0.006	0.017	0.044	0.079	0.293	0.444	0.666	0.889	0.974	0.997
	Ask	0.006	0.013	0.051	0.183	0.256	0.423	0.616	0.847	0.955	0.998
Quotes	Bid	0.005	0.011	0.061	0.176	0.357	0.607	0.746	0.891	0.965	1.000
	Ask	0.002	0.006	0.033	0.116	0.241	0.339	0.530	0.792	0.983	0.999

Notes:

- (1) Figures represent p-values. The table shows where the announcement depths fall relative to each stock's/liquidity provider's own empirical distribution.
- (2) Empirical distributions are constructed for each liquidity provider within each stock by averaging 14 random draws 1000 times each.
- (3) The pre- (post-) announcement period observation is the average of the 14 half-hour observations immediately prior (subsequent) to 11:35 AM EST December 19, 1990.
- (4) The Federal Open Market Committee (FOMC) met on December 17 and 18, 1990.

Table 15

Statistical Test of Depth Contribution around the January 9, 1991 Federal Reserve Announcement

Liquidity Provider	Side of Market	Percentage of Announcements having depth less than or equal to the figure shown									
		5%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Pre-Announcement Period											
Specialist	Bid	0.005	0.009	0.040	0.100	0.210	0.373	0.605	0.728	0.865	0.984
	Ask	0.016	0.027	0.077	0.180	0.303	0.493	0.631	0.815	0.909	0.964
LOB	Bid	0.004	0.013	0.042	0.152	0.224	0.377	0.477	0.707	0.918	0.991
	Ask	0.004	0.010	0.038	0.138	0.225	0.379	0.544	0.752	0.912	0.994
Quotes	Bid	0.002	0.005	0.050	0.108	0.214	0.315	0.521	0.737	0.911	0.991
	Ask	0.003	0.012	0.030	0.052	0.165	0.345	0.505	0.772	0.936	0.988
Post-Announcement Period											
Specialist	Bid	0.002	0.007	0.033	0.138	0.219	0.366	0.494	0.663	0.812	0.967
	Ask	0.002	0.005	0.018	0.074	0.192	0.402	0.570	0.724	0.864	0.983
LOB	Bid	0.005	0.008	0.063	0.014	0.243	0.368	0.491	0.654	0.845	0.980
	Ask	0.005	0.015	0.061	0.124	0.223	0.360	0.699	0.867	0.961	0.998
Quotes	Bid	0.004	0.007	0.023	0.051	0.152	0.251	0.391	0.678	0.948	0.989
	Ask	0.002	0.005	0.020	0.106	0.180	0.294	0.508	0.669	0.942	0.995

- Notes:
- (1) Figures represent p-values. The table shows where the announcement depths fall relative to each stock's liquidity provider's own empirical distribution.
 - (2) Empirical distributions are constructed for each liquidity provider within each stock by averaging 14 random draws 1000 times each.
 - (3) The pre- (post-) announcement period observation is the average of the 14 half-hour observations immediately prior (subsequent) to 11:35 AM EST January 9, 1991.

Figure 1
 The Limit Order Book for Waban Incorporated on November 13, 1990 at 10:30 AM

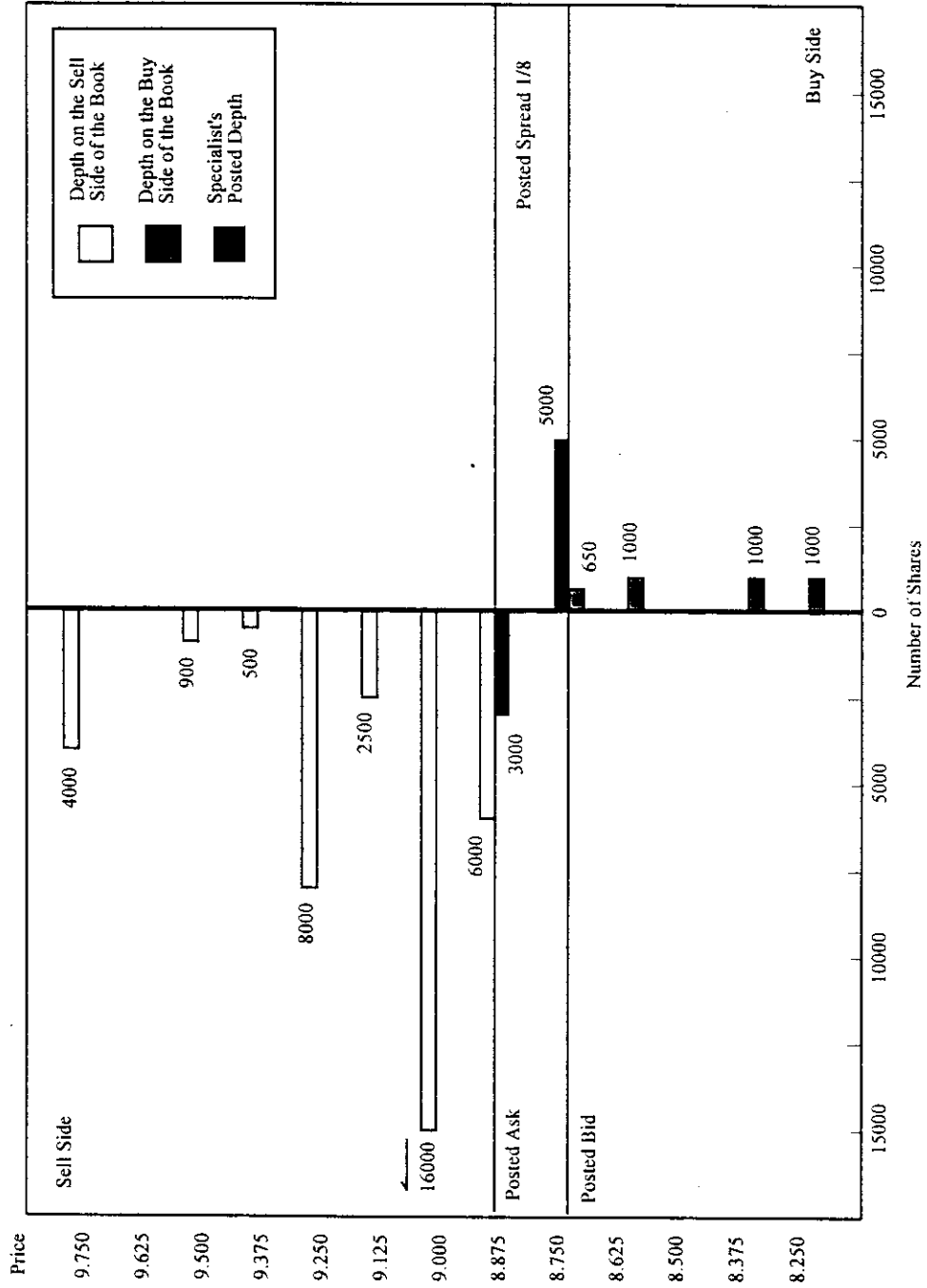


Figure 2

The Limit Order Book for Waban Incorporated on November 13, 1990 at 11:00 AM

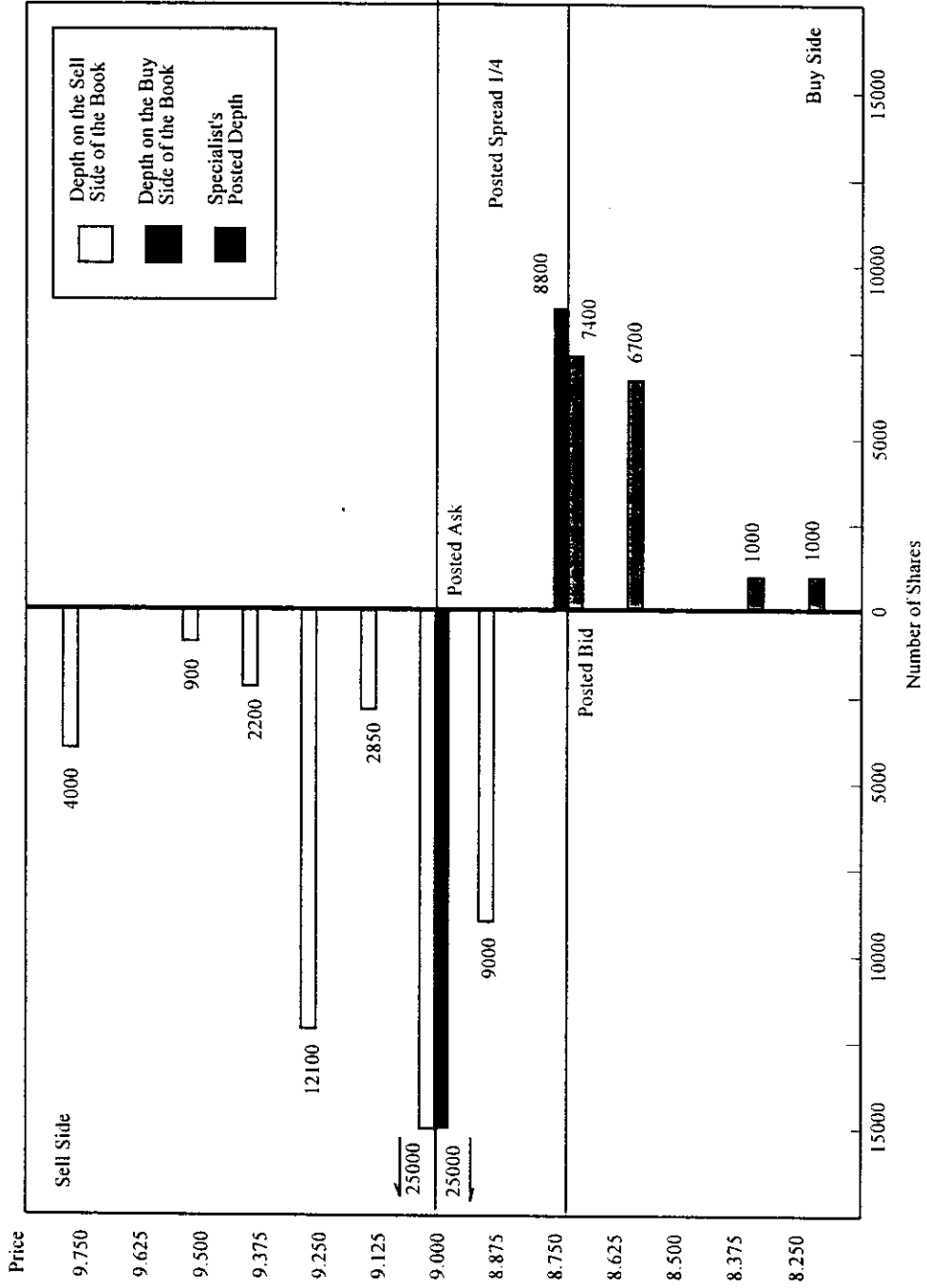


Figure 3
 The Limit Order Book for Waban Incorporated on November 13, 1990 at 11:10 AM

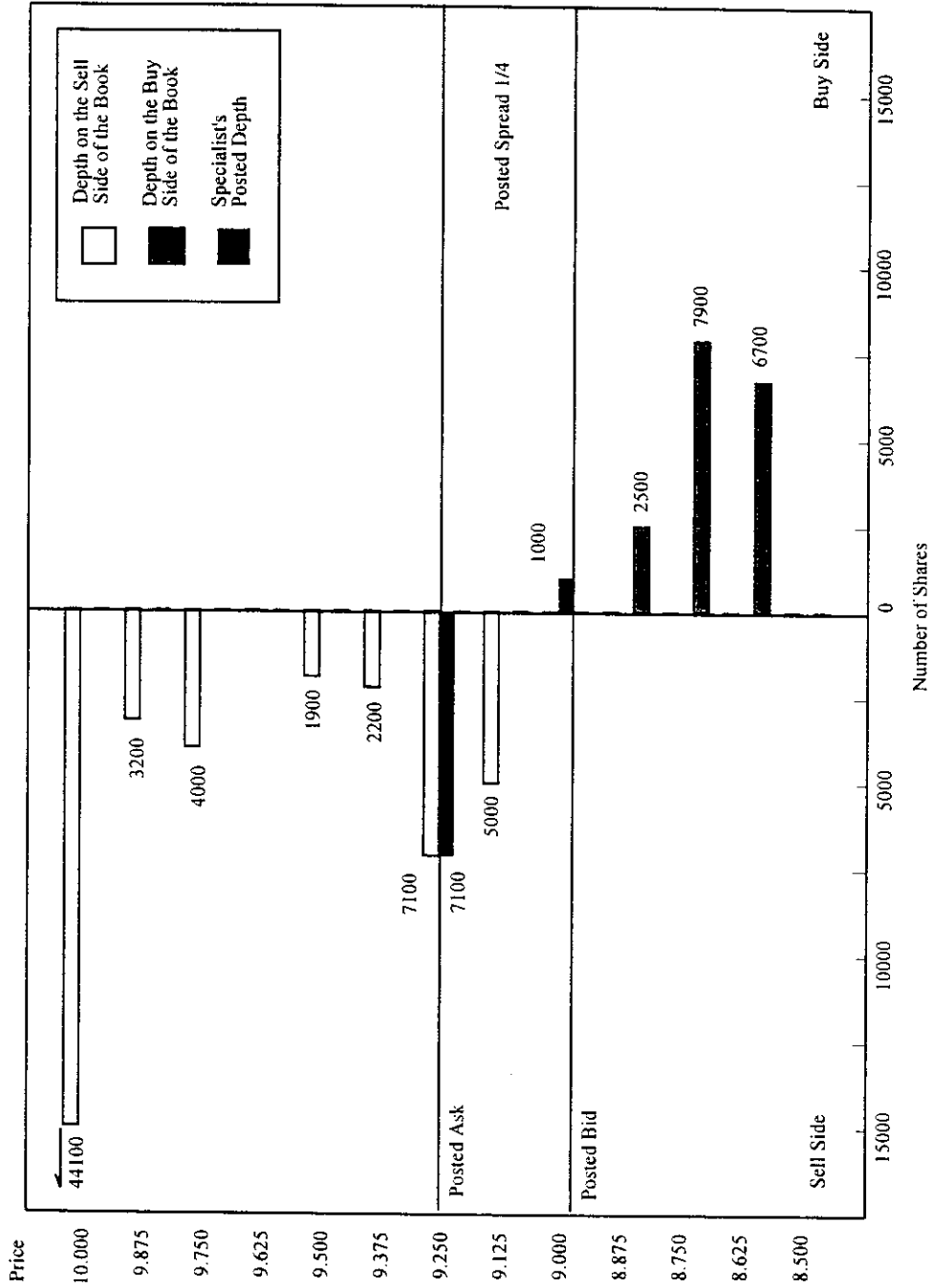


Figure 4

The Limit Order Book for Waban Incorporated on November 13, 1990 at 1:00 PM

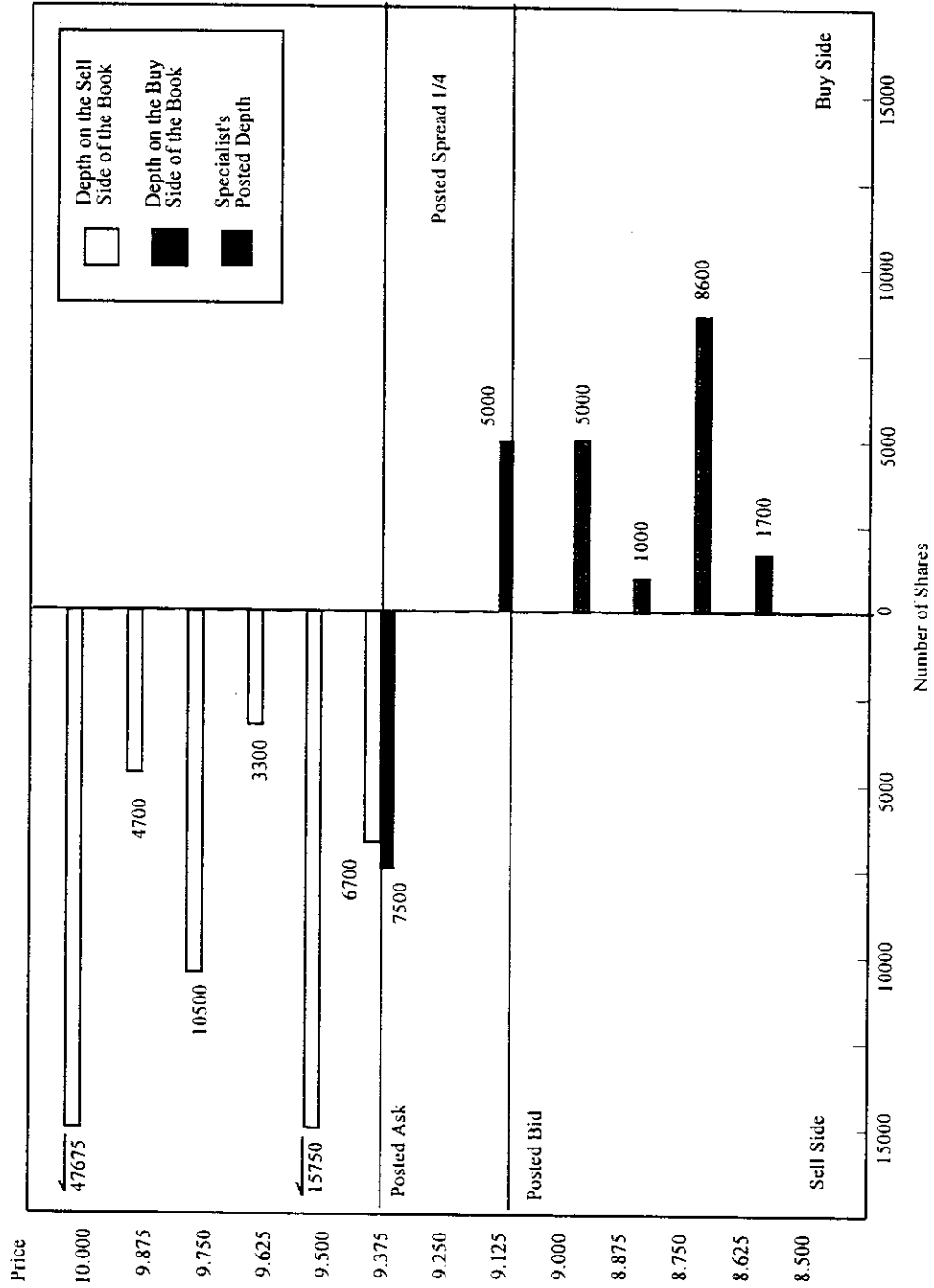


Figure 5

Summary of Market Activity for the Waban Incorporated Example

