Are Transactions and Market Orders More Important Than Limit Orders in the Quote Updating Process?*

Ron Kaniel
Finance Department
The Wharton School
University of Pennsylvania
Philadelphia, PA 19104-6367
Tel: (215) 382-9434
Fax: (215) 898-6200
Email: kaniel73@wharton.upenn.edu

Hong Liu
The Olin School of Business
Campus Box 1133
Washington University
St. Louis, MO 19104-6367
Tel: (314) 935-5883
Fax: (314)-935-6359
Email: liuh@mail.olin.wustl.edu

October 20, 1998

Abstract

Transactions, market orders and limit orders are three major factors which affect a specialist's information set and her inventory position. In modeling a specialist's quote updating process, before any exclusion of any of these factors, one should first address the fundamental question of their relative importance in this process. This question, however, has received little attention both in the theoretical and empirical microstructure literature. Using a simple nonparametric test we investigate the relative importance of these three factors. We demonstrate that both transactions and market orders affect the quote updating process significantly more than limit orders, and that transactions affect it more than market orders. Furthermore, we find that market orders convey more information than limit orders about the value of the underlying security. These results hold even after controlling for transaction and order size.

*We thank Domenico Cuoco, Simon Gervais, Bruce Grundy, Chris Jones, Kenneth Kavajecz, Krishna Ramaswamy, Robert Stambaugh and S. Viswanathan for their kind help and valuable advice. Any comments will be greatly appreciated.

1 Introduction

A focal point in the microstructure literature is the modeling of a specialist's quote updating process. This is true for both inventory control models[1] and asymmetric information models[2]. Identifying the relative importance of different factors can help us to construct models which incorporate important features in a specialist's decision making process, but even more important is the fact that once we are able to identify which factors have more influence we can start to address the question of why one influences the quote more than the other. In this paper we provide empirical evidence which shows that transactions and market orders are significantly more important than limit orders in a specialist's quote updating process, and that market orders convey more information than limit orders about the value of the underlying security.

Empirical research in microstructure has benefited significantly from the introduction of intraday data. Specifically, the use of intraday data has helped in evaluating the relative influence of different factors on the quote updating process. Madhavan and Smidt (1991) demonstrate that: a trade in an active stock has a smaller impact than the corresponding trade in a less active stock; large blocks have a greater impact than small blocks; a block buy has a greater price impact than the corresponding block sale. Hasbrouck and Sofianos (1993) show that a trade in which a specialist participates has a higher immediate impact on the quotes than a trade with no specialist's participation. Hasbrouck (1991) finds that larger trades have a stronger effect than smaller ones. Furthermore, he obtains that trades which occur when the spread is wide have a larger effect than those which occur when the spread is narrow.

One feature of the trading process, which has been receiving more and more attention, is the specialist's limit order book. Cohen, Schwartz and Withcomb (1981) demonstrate that competition from limit orders causes the specialist to offer a narrower spread and thus reduce overall costs of liquidity. O'Hara and Oldfield (1986) construct a model in which a risk averse specialist faces both limit orders and market orders. They demonstrate that the bid-ask spread can be decomposed into a portion for the known limit orders, a risk-

[1] See, for example, Amihud and Mendelson (1980), Ho and Stoll (1983) and O'Hara and Oldfield (1986).

[2] See, for example, order-based asymmetric information models which originated from Kyle (1985) and transaction based models which originated from Glosten and Milgrom (1985).

neutral adjustment for expected market orders, and a risk adjustment for market orders and inventory value uncertainty.[3] Rock (1996) focuses on how a market maker's inventory problem is affected by the existence of the limit order book. His key result is that uninformed limit orders exacerbate the inventory problem and thus delay the full adjustment to an inventory shock. Easley and O'Hara (1991) demonstrate that the existence of the book can induce price effects even when the orders in the book are known to be uncorrelated with information. Their observation is that by providing an alternative trading mechanism, the book can divert order flow and hence change the information content of the remaining trades.

Some of the earlier work in market microstructure completely ignores limit orders. For example Glosten and Milgrom (1985) is a transaction based model, and in Kyle (1985) the price process evolves due to the use of market orders. These papers, by ignoring the existence of limit orders, actually make an implicit assumption that transactions and market orders affect the price process more than limit orders. This implicit assumption, however, has never been tested. Moreover, the relative influence of transactions, market orders and limit orders on a specialist's depth setting process is also an open issue.

One of the factors which affects the relative importance of different orders is the amount of information conveyed by each type of order. A trader who has to decide whether to use a market order or a limit order has to take into account different factors. A market order is guaranteed execution, but if the order is larger than the prevailing bid (ask) depth then she will bear price risk. On the other hand, a limit order has no price risk, but it has execution risk. Furthermore, by placing a buy (sell) limit order one actually gives other participants a free put (call)option. An uninformed trader who requires immediate execution will prefer to use a market order. However, if this uninformed trader is patient she may prefer to submit a limit order. By submitting a limit order she is bearing execution uncertainty, but conditional on execution she will receive a better price in most cases. Harris and Hasbrouck (1996) find that limit orders placed at the prevailing quote or better perform better than market orders, even after imputing a penalty for unexecuted orders and taking into account market order price improvement.

[3]They model the trading process as a sequence of call actions in which at the beginning of each call auction the amount of limit orders is known and the amount of incoming market orders is random.

An informed trader has to consider the value of her information in addition to the above mentioned factors. If her information is very short lived and she intends to execute a small order, then she would probably prefer to use a market order. On the other hand, if she intends to execute a large order, she must also take into consideration how far away the current market price is from her own valuation. If her valuation is relatively close to the current market, then executing a large market order entails exposure to price risk, which may cause him to actually purchase the stock at a price above her valuation, or sell the stock at a price below her valuation. Thus, in such cases she may prefer to submit most of her orders as limit orders. If her information is long lived she will be more reluctant to use large market orders since by doing so she is signaling to the market that the stock is overpriced/underpriced and thus loses her informational advantage.[4]

Another consideration, when comparing the effects of market and limit orders, is how they affect a specialist's inventory position. An incoming market order has a direct effect on the specialist's inventory if the specialist takes part, or all, of the other side of the order. Hasbrouck and Sofianos(1993) find that the specialist participation rate[5] is between 10% for actively traded stocks and 19% for infrequently traded stocks. If the incoming order is executed against a limit order then the specialist's current inventory position is not affected, but by reducing the depth provided by the book there is an indirect effect on the specialist's future inventory position. Similarly, an incoming limit order can potentially affect the specialist's future inventory positions. although it does not have a direct effect on her current inventory position.

In this paper we test the relative importance of transactions vs. limit orders and the relative importance of market orders vs. limit orders in a specialist's quote updating process. The formal measure by which we define relative importance will be introduced in Section 2. We perform the test on the 144 stocks recorded in the TORQ database. When trying to understand the specialist's quote updating process one should not restrict oneself to prices (i.e., bid and ask), but should also consider the quoted depths (i.e., bid depth and ask depth), as also recognized by Kavajecz(1995). Therefore, we conduct our tests both

[4]For more details on strategy placement issues see Easley and O'Hara (1991), Foucault (1993), Chakravarty and Holden (1995), Angel (1992) and Harris (1994).

[5]The traditional measure of a specialist's participation rate is defined as $\frac{\text{Specialist purchases+Specialist sales}}{\text{Total purchases and sales}}$.

on prices and on depths. We find that transactions and market orders are significantly more important than limit orders. When we group the stocks according to trading activity, we find that for each of the top 9 deciles the null that transactions and limit orders are equally important is rejected against the alternative (i.e., transactions are more important) with a p-value of less than 0.01.[6] This result, in general, still holds after controlling for transaction/order size. Furthermore, we demonstrate that one of the reasons that market orders are more important than limit orders is that they convey more information about the value of the underlying security.

The rest of the paper is organized as follows. In Section 2 we define the *measure of relative importance* that we use later. Section 3 discusses the empirical methodology and the data source. The results are presented in Section 4. Concluding remarks are exhibited in Section 5.

2 Measuring Relative Importance

The main objective of our paper is to measure the *relative importance* of transactions vs. limit orders and market orders vs. limit orders in the specialist's quote updating process. Unless specified otherwise the term "quote" throughout the paper refers to any of the following: bid, ask, bid depth, ask depth.

To clarify the difference between a transaction and a market order we note that execution of market orders are only a subset of the set of all transactions. A transaction can be any one of the following: a transaction between two floor brokers, a transaction between a specialist and a floor broker, a floor broker transacting against the limit order book, a transaction on the upstairs market, a transaction on a regional exchange, a specialist transacting against the limit order book, crossing of buy and sell limit orders on the specialists book, a specialist taking the other side of a market order, a floor broker taking the other side of a market order, executing an incoming market order against the limit order book.

Definition. Transactions/market orders are **more important** than limit orders in a specialist's quote updating process if: [7]

$$\frac{\#\text{ of quote changes after transactions/market orders}}{\#\text{ of transactions/market orders}} > \frac{\#\text{ of quote changes after limit orders}}{\#\text{ of limit orders}}$$

[6] Similar results hold when we test market orders vs. limit orders.

[7] The definition includes two inequalities, one for transactions, the other for market orders.

For example, if the sample ratio of market orders vs. limit orders is 1:1, but the quotes change 1000 times after market orders but only 100 times after limit orders, then according to the above definition market orders are more important than limit orders.

3 Empirical Methodology and Data Source

3.1 Empirical Methodology

Quote changes are a discrete variable. 90.4% of the bid changes are 1 tick, 8.2% are 2 ticks and only 1.4% are more than 2 ticks (for ask changes the relevant percentages are 90.3%, 8.9% and 0.8%). Thus, a simple regression approach is clearly inappropriate for intraday data. An alternative approach could be to use a limited dependent variable model such as ordered probit or logit. In this case one has to address the issue of what is the appropriate specification to be used. Furthermore, one should recall that it is quite unclear how the coefficients in the ordered probit or logit models should be interpreted (See Green 672-674). In addition, parametric tests can easily be adversely affected by a few outliers in the sample. In order to avoid the above parametric modeling limitations we use a nonparametric approach, similar to that of Rubinstein (1985), to test the relative importance. As explained in Rubinstein (1985), the nonparametric test is "distribution-free" since it does not require a specific assumption on the population distribution from which the sample was drawn. Nor do nonparametric tests need to impose *a priori* restrictions on the relationship among variables. Unfortunately, nonparametric tests have much less power than parametric tests. However, with a large enough sample, as we have in this study (in the whole sample we have more than 40,000 relevant quote changes), we still get enough testing power, as will be shown later.

Tested hypotheses: Throughout the paper we have the following two hypotheses tested:

1. Transactions vs. limit orders

   H_0^T : Transactions and limit orders are equally important.

   H_1^T : Transactions are more important than limit orders.

2. Market orders vs. limit orders

H_0^M : Market orders and limit orders are equally important.

H_1^M : Market orders are more important than limit orders.

For the first hypothesis we conduct the test in the following way.[8]

Let P_{trans} be the probability of an occurrence of a transaction at any given point in time and let $1 - P_{trans}$ be the probability of an occurrence of a limit order. Let n be the total number of quote changes that occur directly after either a transaction or a submission of a limit order,[9] and let QTR be the number of quote changes which occur directly after transactions (so that $n - QTR$ is the number of quote changes which directly follow limit orders). Under the null hypothesis H_0^T, the probability that out of these n quote revisions QTR or more are preceded by a transaction is well-approximated by

$$1 - N\left[\frac{QTR - P_{trans}\, n}{\sqrt{P_{trans}(1 - P_{trans})\, n}}\right]$$

where N is the standard normal cumulative distribution function.

Performing this test using the TORQ database is straightforward. We first construct the time sequence of all events: orders,[10] transactions, and quote changes. Then we use the sample frequencies of transactions and limit orders to approximate P_{trans}. To find n we use the number of quote changes that are immediately preceded by either a transaction or a limit order. Then out of these we check how many are preceded by a transaction (QTR) . Finally we compute the above probability. If the probability is less than 0.05, we reject the null.

3.2 Data and Construction of Event Series

The TORQ database (compiled by NYSE) covers 144 stocks from November 1, 1990 through January 31, 1991 (63 trading days). It includes all transactions, all orders submitted via one of the automated routing systems, and all quote changes for these stocks. The 144 stocks include 15 stocks from each of the top 4 market cap deciles on the NYSE and 14

[8]The procedures for testing the two hypotheses are essentially the same. We shall refer to the second hypothesis only when the procedure differs from the procedure used to test the first hypothesis.

[9]By "directly after" we mean that the quote change is the first activity after the transaction. We will elaborate on this issue in Section 3.2.3.

[10]Throughout the paper, limit orders include both submission of limit orders and cancelations of limit orders.

stocks from each of the lower 6 deciles.[11] It is one of the few publicly available data sets which include limit orders, market orders, transactions and quotes in such a high frequency (for high trading frequency stocks, the record is almost by second).[12]

The TORQ data set contains four files: CT.BIN, CQ.BIN, CD.BIN and SOD.BIN. CT.BIN is the consolidated transaction file. It records transactions and associated data. CQ.BIN is the consolidated quote file. It records every quote change during the sample period. CD.BIN is the consolidated audit trail file. It is an extension of CT.BIN. SOD.BIN is the consolidated order file. It includes all orders submitted electronically. These are subset copies of internal NYSE files.[13]

Since CD.BIN is the audited and extended version of CT.BIN, we use CD.BIN instead of CT.BIN in our analysis. The other two files we use are CQ.BIN and SOD.BIN. For each stock, we extract from the CQ.BIN a series which includes date, time and quotes (bid, ask, bid depth and ask depth). From CD.BIN we extract a series which includes date, time and transaction details of each transaction. Similar series are extracted for all orders from SOD.BIN. After merging these different series, we can construct a time series of all activities for each stock.

3.2.1 Preliminary screening

Before conducting the tests we apply the following screening criteria:

- Discard any records which correspond to a time before 10:00am or after 3:00pm, thus avoiding the influence of any special opening or closing effects. Since the NYSE opens the trading day with a call market, one might observe many limit orders that are submitted in the early morning without observing any quote revisions in that period. In general the specialist changes her quotes only at the end of the call market. Discarding the morning data frees us from the possible biases[14] caused by this call market effect. At the end of the day, the specialist is required to execute market on

[11] A detailed list of the stocks appearing in the data, ranked according to market capitalization at the end of 1990, can be found in Kavajecz(1995).

[12] Unfortunately it does not contain information on specialists inventory positions, nor is it possible to distinguish trades which were made by a specialist to her own account from trades which were made by floor brokers.

[13] See Hasbrouck (1992) and Hasbrouck and Sosebee (1992) for more detailed descriptions of the TORQ database and the institutional backgrounds of trading procedures.

[14] in favor of the alternative

close orders that are submitted throughout the day. Thus, part of the transactions that are executed during that period are known in advance. Furthermore, we do not want our results to be affected by the fact that the specialist and/or other market participants might want to control their overnight inventory exposure, and thus behave differently during that period.[15]

- Discard any quote records that are not NYSE quotes (i.e., ITS quotes). In many cases ITS quotes are auto quotes which just follow the NYSE quotes. Furthermore, Kavajecz (1995) shows that the best ITS quote often entails a substantially smaller depth. Thus we feel that it is safe to assume that the effect of the ITS quotes on a specialist's quote updating process is negligible.

3.2.2 Estimating population frequencies

When calculating the relevant sample frequencies the following criteria are used:

- Do not count any orders that are not straight market orders or standard limit orders. Straight market orders and standard limit orders account together for about 95% of the SuperDOT orders. Thus we do not count market on close orders or other orders with rarely used qualifications. A market on close order is an order to be executed only at the end of the day. A specialist's reaction to such an order will probably be different from her reaction to a submission of a regular market order. Market on close orders account for about 2% and are not part of our interest in this paper.[16]

- Do not count any limit buy (sell) orders that are submitted with a limit price that is lower (higher) than the prevailing bid (ask). These limit orders are less likely to affect a specialist's quote than those at or inside the quote. Thus, by ignoring them we are biasing the test in favor of the null.[17] [18]

It should be stressed that even though a certain activity is not part of a given test it is not dropped from the merged time series. Although these activities are not counted as part

[15] See, for example, Hong and Wang (1995).

[16] These numbers are from Harris and Hasbrouck (1996).

[17] In our sample around 70% of the limit orders are submitted either within or at the quotes, and 85% are submitted within two ticks away from the current quotes.

[18] We also conducted all tests when we only exclude limit buy (sell) orders submitted with a price more than two ticks lower (higher) than the prevailing bid (ask). The results are stronger.

of the relevant sample frequencies, they are part of a specialist's information set. Excluding them from the merged time series would distort the results.

3.2.3 Attributing quote revisions

Throughout the paper we conduct all our tests for the following variables: bid changes; ask changes; bid depth changes; ask depth changes; quote changes (i.e., a change in any of the previous four).

We first describe the general method in attributing quote changes, and then describe some more details.

The general procedure:

Transaction If the next activity (in the consolidated time series) after a transaction is a quote change, attribute the quote change to this transaction.

Limit order If the next activity after a limit order is a quote change, attribute the quote change to this limit order.

Market order In general, a market order can either be executed at the prevailing quotes, stopped by the specialist, or executed with an immediate price improvement. Thus in each one of the following cases we attribute a quote change to the given market order: 1) The market order is executed and the execution is followed by a quote change. 2) The market order is stopped and the next activity after the order is stopped is a quote change. 3) the market order is followed by a quote change.[19]

It is easy to see that the above procedure never attributes a particular quote revision to both a transaction and a limit order. Similarly, it does not attribute a quote revision to both a market order and a limit order.[20]

There are a few details that have to be addressed:

- If there appear a few same activities (for example a few transactions) with the same time stamp then a quote change will be attributed to at most one of them.[21]

[19]Note that if a market order gets an immediate price improvement it could be that in this case the quote change will precede the relevant transaction.

[20]A quote revision can be attributed to both a transaction and a market order. This does not cause any problems since we are always comparing either transactions to limit orders or market orders to limit orders. On the other hand, some quote revisions may be not attributed to any of these three events.

[21]This problem arises only for very actively traded stocks.

- In some cases a limit order and a transaction/market order have the same time stamp. In these cases we attribute the relevant quote change, if any, to the limit order, thus biasing the test in favor of the null.

- The process of physically changing quotes takes several seconds. Thus, the following scenario is possible: a specialist receives a limit order and decides to change the quotes, as she is in the process of changing the quotes a transaction is reported via ITS. In such a case the quote change may be mistakenly attributed to the transaction. It should be stressed that this problem arises essentially only for the extremely active stocks (the highest activity decile). In order to partially adjust for this problem we attribute a quote change to a transaction only if the preceding event (any event not only a limit order) before the transaction is at least 10 seconds away from the quote change. Similar procedures are applied to market and limit orders.[22]

3.2.4 Time stamp problem

As explained in Hasbrouck and Sosebee (1992), due to the difference in the reporting mechanisms for trades and quotes, a quote that is changed subsequent to a transaction may have an earlier time stamp than the one for the transaction. Our quote attributing procedure will not attribute the quote change to the transaction or market order in such cases. Furthermore, if such a time reversal occurs we might attribute a quote change to a limit order when that limit order should not have been attributed the quote change. Note that both of these effects bias the test in favor of the null hypotheses.[23]

3.3 Trading activity

Specialists who handle stocks with different trading activities may behave differently. Hasbrouck and Sofianos (1993) find that a specialist's participation rate is about 19% for inactively traded stocks, whereas for actively traded stocks the participation rate drops to about 10%. Furthermore, the information revelation process of actively traded stocks may

[22] In the whole sample, for less than 1% of the quote changes which appear after a transaction, there is a limit order which precedes the transaction and is less than 10 seconds away from the quote change. For the highest activity decile the corresponding percentage is 3.5%. The corresponding percentages for market and limit orders are similar.

[23] Hasbrouck(1991) reverses the time sequence if a quote change appears within 5 seconds prior to a transaction. As explained above, using such a procedure will be in favor of the alternative hypotheses.

be also different from that of inactively traded stocks. In order to control for different trading activities we sort the stocks in the TORQ data set according to the measure of trading activity we define below and group them into deciles.

Definition. **Trading activity** for a given stock is defined as the total number (over all 63 trading days) of transactions + limit orders.[24]

Table 1 exhibits some descriptive data about the 144 stocks studied. The stocks are grouped into deciles according to trading activity. The table records average frequency of each event for each decile on a daily basis.

The stocks reflect a wide range of activity. The average measure of *trading activity* of the most active decile is more than 170 times that of the least active decile.[25] On the other hand, the average number of quote changes of the most active decile is only about 70 times that of the least active decile.[26] This indicates that transactions and market orders convey more information and/or have a more profound effect on specialists' inventory position for inactive stocks than the corresponding activities for active stocks. This finding is consistent with Madhavan and Smidt (1991) who demonstrate that a trade in an active stock has a smaller impact than the corresponding trade in a less active stock. It is also consistent with Hasbrouck and Sofianos (1991) who find that specialists have higher participation ratio in inactive stocks than in active stocks (19% for the inactive vs. 10% for the active). On the other hand, this difference may imply that liquidity traders tend to use actively traded stocks for their better liquidity, and thus causing the ratio of informed to uninformed trades/orders to be higher for inactively traded stocks.

One other phenomenon worth noting is that, on average, the number of depth changes is more than twice as much as the number of price changes. Therefore, as pointed out in Kavajecz (1995), to thoroughly understand the quote updating process, one also has to consider the mechanism of depths revisions.

[24] Other measures may be: transactions; transactions + limit orders; transactions + limit orders + market orders. These measures give similar decile rankings as the one we use.

[25] The corresponding ratios for the different components of the *trading activity* are 144 for limit orders and 185 for transactions. For market orders, it is 160.

[26] The corresponding ratios for the bid and the ask are around 30, while the ratios for the bid depth and ask depth are 63 and 90 respectively.

Table 1: Descriptive Statistics

Decile[a]	OBS	NLMT [b]	NMKT [c]	NSTP [d]	NT [e]	NQUOTE [f]	NBID [g]	NASK [h]	NBIDDEPTH [i]	NASKDEPTH [j]
Active	15	128.51	150.73	37.68	304.47	102.34	18.81	19.05	48.15	50.81
2	15	36.18	39.16	9.37	73.70	42.45	9.52	9.57	20.13	20.97
3	15	20.66	32.82	7.80	51.69	24.13	6.79	6.79	11.21	12.18
4	15	14.03	19.96	4.36	32.28	21.09	4.99	5.02	10.28	10.17
5	14	11.99	10.68	1.71	20.76	15.90	5.08	4.93	7.51	7.59
6	14	8.53	6.26	1.51	15.29	10.58	3.56	3.55	5.20	4.69
7	14	6.32	3.64	0.83	9.03	8.76	2.67	2.61	4.12	4.10
8	14	4.29	2.29	0.37	5.92	5.35	1.79	1.78	2.73	2.43
9	14	2.60	1.73	0.20	3.85	3.84	1.37	1.35	2.13	1.63
Inactive	14	0.89	0.94	0.06	1.64	1.49	0.66	0.67	0.76	0.56
All	144	24.13	27.76	6.62	53.63	24.26	5.65	5.66	11.53	11.85

[a] The stocks are sorted according to activity (15 in each of the first four deciles and 14 in each of the last six). Activity is defined as the total number (over all 63 trading days) of transactions + limit orders.

[b] Average across stocks of the average number of limit orders per day.

[c] Average across stocks of the average number of market orders per day.

[d] Average across stocks of the average stopped orders per day.

[e] Average across stocks of the average number of transactions per day.

[f] Average across stocks of the average number of quote changes per day.

[g] Average across stocks of the average number of bid changes per day.

[h] Average across stocks of the average number of ask changes per day.

[i] Average across stocks of the average number of bid depth changes per day.

[j] Average across stocks of the average number of ask depth changes per day.

4 Results

Specialists who deal in stocks which have similar activity characteristics tend to react similarly to similar activity. Therefore, we pool the stocks in each activity decile. By pooling we do not mean that all the stocks are combined to make one time series of activity. Instead, we first construct a relevant time series of activity for each stock (see Section 3.2). Then, according to the procedure in Section 3.2.3, we attribute quote revisions to the relevant preceding activity for each stock. Finally, we use the information in Table 1 to obtain the probabilities of observing a transaction, a market order or a limit order in the pooled sample. Then we conduct the test proposed in Section 3.1 above. Note that the number of observations for a test which compares the relative importance of transactions and limit orders is the total number, across all stocks in the relevant decile, of quote revisions which are attributed to either transactions or limit orders. Similarly, for a test which compares market orders and limit orders, the number of observations is the total number of quote revisions which are attributed to either a market order or a limit order.

Table 2 exhibits the results for both tests (transactions vs. limit orders and market orders vs. limit orders).[27] Except for the lowest activity decile, the null is rejected in both tests for bid and ask changes as well as for bid depth and ask depth changes, with a p-value of less than 0.01.[28] For the lowest activity decile, however, we do reject the null in both tests for bid and ask changes with a p-value less than 0.01, but we are not able to reject the null in either test for bid depth or ask depth. As seen from Table 1 the average number (per day) of quote changes for stocks in the lowest activity level is less than 2. Furthermore, the average number of transactions + market orders + limit orders is less than 4. Thus for these stocks the time between two adjacent events could be very long.[29] When we pool all 144 stocks, the null is rejected with a p-value of less than 0.01 in both tests for bid and ask changes as well as for bid depth and ask depth changes.[30].

[27]For brevity, throughout the paper we shall report the results for bid changes and bid depth changes. Unless stated otherwise, the results for other variables (ask, ask depth and quote) are similar to the ones we report.

[28]The only other case in which the null is not rejected is in the test of market orders vs. limit orders for depths changes in the third decile.

[29]For the last decile the average time between a limit/market order and the quote change that is attributed to that order is 23.5 minutes. For decile 9 the average goes down to 5.7 minutes, and for the top 5 deciles it is below 2 minutes.

[30]Out of those cells in the table for which the p-value is less than 0.01, more than 90% have a p-value less

Table 2: Bid, Ask, Bid Depth, and Ask Depth[a]

	Transaction vs. Limit				Market vs. Limit			
Decile[b]	PBID[c]	PASK[d]	PBDEP[e]	PADEP[f]	PBID	PASK	PBDEP	PADEP
Active	0.00[g] (12362)	0.00 (12663)	0.00 (26607)	0.00 (28511)	0.00 (6952)	0.00 (7114)	0.00 (17150)	0.00 (18253)
2	0.00 (5801)	0.00 (5685)	0.00 (12051)	0.00 (12672)	0.00 (2879)	0.00 (2732)	0.00 (7423)	0.00 (7568)
3	0.00 (5151)	0.00 (5260)	0.00 (7480)	0.00 (8571)	0.00 (2584)	0.00 (2567)	0.57 (4523)	0.93 (5204)
4	0.00 (3420)	0.00 (3280)	0.00 (6300)	0.00 (6417)	0.00 (1807)	0.00 (1711)	0.00 (3916)	0.00 (3960)
5	0.00 (3293)	0.00 (3254)	0.00 (5457)	0.00 (5127)	0.00 (1613)	0.00 (1518)	0.00 (3110)	0.00 (2728)
6	0.00 (2339)	0.00 (2326)	0.00 (3461)	0.00 (2940)	0.00 (1177)	0.00 (1111)	0.00 (2078)	0.00 (1652)
7	0.00 (1710)	0.00 (1660)	0.00 (2600)	0.00 (2649)	0.00 (850)	0.00 (789)	0.00 (1575)	0.00 (1497)
8	0.00 (1196)	0.00 (1256)	0.00 (2054)	0.00 (1703)	0.00 (560)	0.00 (574)	0.00 (1276)	0.00 (866)
9	0.00 (940)	0.00 (913)	0.00 (1286)	0.00 (984)	0.00 (490)	0.00 (466)	0.00 (757)	0.00 (530)
Inactive	0.00 (344)	0.00 (341)	0.11 (436)	0.04 (317)	0.00 (180)	0.00 (152)	0.07 (260)	0.70 (157)
All	0.00 (36556)	0.00 (36638)	0.00 (67732)	0.00 (69891)	0.00 (19092)	0.00 (18734)	0.00 (42068)	0.00 (42415)

[a] In parentheses, we include the number of observations in the corresponding test.

[b] The stocks are sorted according to activity (15 in each of the first four deciles and 14 in each of the last six). Activity is defined as the total number (over all 63 trading days) of transactions + limit orders.

[c] Probability of the sample event under the null for bid changes .

[d] Probability of the sample event under the null for ask changes .

[e] Probability of sample event under the null for bid depth changes.

[f] Probability of sample event under the null for ask depth changes.

[g] More than 90% of 0.00's reported here are less than 10^{-3}.

4.1 Controlling for size

A possible explanation of why transactions/market orders are more important could be that transactions/market orders are simply larger than limit orders, thus we are only picking up the size effect, as opposed to an inherent effect which is related to the differences between transactions/market orders and limit orders. In order to verify that our results are not simply driven by the difference in sizes, we next control for size.

We partition the data into the following four transaction/order size regions: ≤ 500; $500-1500$; $1500-5000$; and > 5000. In order to justify the normal distribution approximation, and in order to have enough test power we report the relevant p-value only if there are at least 50 observations (i.e., 50 attributed quote changes).[31]

Table 3 records the results for both transactions vs. limit orders and the market orders vs. limit orders tests. Except for the lowest decile, the null is rejected with a p-value of less than 0.01 in all the cases except for bid depth changes when comparing market orders vs. limit orders for an order size above 5000 shares. In this case, the p-values are <u>greater</u> than 0.01 for all the relevant deciles, and for most deciles are even greater than 0.1.

Another way for controlling for size is to compare the transaction/order size to the prevailing quoted depth. Since the control variable in this case is the depth itself we conduct this test–only for prices (i.e., bid and ask). We partition transactions/orders into two "size" groups. The first group consists of transactions/orders which are smaller than the prevailing quoted depth. The second group consists of transactions/orders that are larger than the prevailing depth. Furthermore, since we want to test how the size of a transaction/order (relative to the quoted depth) affects a specialist's decision, we conduct this test only for transactions and market orders that are executed against the specialist's book.[32] The relevant depth used for a market buy is the ask depth and is the bid depth for a market sell. On the other hand for a limit buy the appropriate depth is the bid depth and for a limit sell it is the ask depth.

The results are reported in Table 4. For the test of transactions vs. limit orders we

---

than 10^{-3}.

[31]Rubinstein(1995) uses 20 as his cutoff point. In our data the ratio of occurrences of transactions to limit orders is about 2.25:1 and the ratio of occurrences of market orders to limit orders is about 1:1. Thus, to be on the safe side, we choose 50 as our cutoff point.

[32]Another reason for excluding (from this test) transactions that are not executed against the book is that it is unclear what is the relevant depth side that should be used given our data set.

Table 3a: Bid, with control for transaction/order size.[a]

	Transaction vs. Limit				Market vs. Limit			
Decile	≤500 [b]	500-1500[c]	1500-5000[d]	>5000[e]	≤500	500-1500	1500-5000	>5000
Active	0.00 [f] (5092)	0.00 (3241)	0.00 (2937)	0.00 (1092)	0.00 (3687)	0.00 (1744)	0.00 (1287)	0.00 (234)
2	0.00 (2083)	0.00 (1664)	0.00 (1431)	0.00 (623)	0.00 (1324)	0.00 (881)	0.00 (571)	0.00 (103)
3	0.00 (2352)	0.00 (1381)	0.00 (1066)	0.00 (352)	0.00 (1428)	0.00 (696)	0.00 (410)	0.00 (50)
4	0.00 (1603)	0.00 (865)	0.00 (716)	0.00 (236)	0.00 (972)	0.00 (476)	0.00 (303)	0.01 (56)
5	0.00 (1479)	0.00 (976)	0.00 (631)	0.00 (207)	0.00 (782)	0.00 (516)	0.00 (272)	NA [g]
6	0.00 (1193)	0.00 (692)	0.00 (362)	0.00 (92)	0.00 (612)	0.00 (373)	0.00 (170)	NA
7	0.00 (803)	0.00 (502)	0.00 (338)	0.00 (67)	0.00 (407)	0.00 (271)	0.00 (161)	NA
8	0.00 (458)	0.00 (420)	0.00 (250)	0.00 (68)	0.00 (221)	0.00 (206)	0.00 (117)	NA
9	0.00 (498)	0.00 (267)	0.00 (157)	NA	0.00 (254)	0.00 (138)	0.00 (86)	NA
Inactive	0.01 (172)	0.01 (88)	0.00 (61)	NA	0.01 (91)	0.05 (51)	NA	NA
All	0.00 (15733)	0.00 (10096)	0.00 (7949)	0.00 (2778)	0.00 (9778)	0.00 (5352)	0.00 (3403)	0.00 (559)

[a] We include the number of observations for the corresponding test in the parenthesis.

[b] Probability of the sample event under the null for the bid changes for the transactions (market orders) and limit orders of at most 500 shares.

[c] Probability of the sample event under the null for the bid changes for the transactions (market orders) and limit orders of more than 500 shares and at most 1500 shares.

[d] Probability of the sample event under the null for the bid changes for the transactions (market orders) and limit orders of more than 1500 shares and at most 5000 shares.

[e] Probability of the sample event under the null for the bid changes for the transactions (market orders) and limit orders of more than 500 shares.

[f] More than 90% of 0.00's reported here are less than 10^{-3}.

[g] A NA appears if the number of observations for a test is less than 50.

Table 3b: Bid Depth, with control for transaction/order size.[a]

	Transaction vs. Limit				Market vs. Limit			
Decile	≤500 [b]	500-1500[c]	1500-5000[d]	>5000[e]	≤500	500-1500	1500-5000	>5000
Active	0.00 [f] (11920)	0.00 (6718)	0.00 (5879)	0.00 (2090)	0.00 (9284)	0.00 (4059)	0.00 (3069)	0.63 (738)
2	0.00 (4597)	0.00 (3439)	0.00 (2964)	0.00 (1051)	0.00 (3177)	0.00 (2351)	0.00 (1629)	0.01 (266)
3	0.00 (3551)	0.00 (1966)	0.00 (1499)	0.00 (464)	0.00 (2558)	0.00 (1143)	0.00 (727)	0.01 (95)
4	0.00 (2694)	0.00 (1607)	0.00 (1474)	0.00 (525)	0.00 (1914)	0.00 (997)	0.00 (774)	0.76 (231)
5	0.00 (2449)	0.00 (1485)	0.00 (1128)	0.00 (395)	0.00 (1491)	0.00 (889)	0.00 (589)	0.34 (141)
6	0.00 (1613)	0.00 (1040)	0.00 (642)	0.00 (166)	0.00 (1014)	0.00 (626)	0.00 (372)	0.86 (66)
7	0.00 (1057)	0.00 (811)	0.00 (616)	0.00 (116)	0.00 (664)	0.00 (524)	0.00 (347)	NA [g]
8	0.00 (867)	0.00 (666)	0.00 (417)	0.16 (104)	0.00 (567)	0.00 (424)	0.00 (236)	NA
9	0.00 (634)	0.00 (378)	0.00 (243)	NA	0.00 (361)	0.00 (225)	0.00 (147)	NA
Inactive	0.09 (171)	0.03 (125)	0.02 (102)	NA	0.05 (98)	0.07 (76)	0.00 (60)	NA
All	0.00 (29553)	0.00 (18235)	0.00 (14964)	0.00 (4980)	0.00 (21128)	0.00 (11314)	0.00 (7950)	0.99 (1676)

[a] We include the number of observations for the corresponding test in the parenthesis.

[b] Probability of the sample event under the null for the bid depth changes for the transactions (market orders) and limit orders of at most 500 shares.

[c] Probability of the sample event under the null for the bid depth changes for the transactions (market orders) and limit orders of more than 500 shares and at most 1500 shares.

[d] Probability of the sample event under the null for the bid depth changes for the transactions (market orders) and limit orders of more than 1500 shares and at most 5000 shares.

[e] Probability of the sample event under the null for the bid depth changes for the transactions (market orders) and limit orders of more than 500 shares.

[f] More than 90% of 0.00's reported here are less than 10^{-3}.

[g] A NA appears if the number of observations for a test is less than 50.

obtain that transactions are more important both when the transaction/order size is greater than the quoted depth and when it is less than the quoted depth. For market orders vs. limit orders orders: for an order size that is greater than the quoted depth market orders are more important, but for an order size that is less than the quoted depth we are able to reject the null only for decile 1 and decile 2. One of the factors by which the NYSE evaluates a specialist is her *performance measure*. One of the criteria in this measure is price continuity (percentage of trades with a $\$\frac{1}{8}$ or less price change). As explained in Ready (1996) a specialist's *performance measure* is one of the factors which are used in the process of assigning new stocks to a specialist firm. If a specialist's quoted depth reflects the combined interest of the limit order book and the trading crowd, then as long as the market order is less than the quoted depth a specialist can maintain her bid and ask quotes and thus achieve a high *performance measure*. If the market order size is greater than the quoted depth then by not changing the quotes the specialist is increasing her inventory exposure risk. Thus, she is more likely to change her quote in this case.

4.2 Informational content of orders

Given the results in the previous sections, another conjecture might be that transactions and market orders are more important than limit orders simply because they tend to affect more a specialist's inventory position but not because they convey more information. To directly investigate this conjecture one has to have data on the specialist's inventory positions. One also has to be able to identify the trades in which the specialist participates. Unfortunately, the TORQ data set does not contain information on specialists' inventory positions, nor is it possible to distinguish trades which are made by the specialist to her own account from trades which are made by floor brokers. Thus, we are not able to completely decouple inventory effects from information effects.

We are, however, able to at least partially decouple them. Both limit orders and market orders which are executed against the book don't have a direct effect on a specialist's inventory position. They may have a second order inventory effect since they may change the specialists future inventory exposure risks. However, if one is willing to accept the assumption that the magnitude of the second order effect is relatively small or similar for the two, then by comparing the relative importance of limit orders vs. market orders which are executed against the book, one can infer if market orders convey more information about the value of the underlying security than limit orders.

Table 5 reports the results of the above test. For an order size of at most 500 shares, for bid changes, the null is rejected for only 3 of the top 9 deciles. Otherwise for the top 9 deciles, the null is still rejected with a p-value of less than 0.01 in almost all cases.[33] This result supports Rock (1996) and Angel (1992) which conjecture that in general informed investors would prefer to use market orders, whereas uninformed investors would tend to use limit orders and place them at or within the prevailing quotes. For bid changes market and limit orders are equally important for small orders, whereas market orders are more important for large orders. This result can be viewed as a counterpart to Hasbrouck (1991) which shows that large trades have a stronger effect than smaller ones.

4.3 Testing stock by stock

For the top four deciles the sample size is large enough to allow us to refine our tests. Instead of pooling the stocks in each activity decile we conduct the tests stock by stock and control for transaction/order size.[34] The transaction/order size are partitioned into two categories. The first includes transactions/orders of at most 500 shares. The second includes those of above 500 shares.

In order to justify the normal distribution approximation and to have enough test power we include a stock is included in only if it has at least a total of 50 observations in each of the six tests. For example, when testing the relative effect on bid changes the screening procedure is as follows. Both for the category of transactions/orders of up to 500 shares and for the category of transactions/orders of above 500 shares: it should have at least a total of 50 observations in each of the following: bid changes attributed to transactions and/or limit orders and bid changes attributed to market orders and/or limit orders.

Table 6 records the results for both transactions vs. limit orders and market orders vs. limit orders tests. When we test the relative importance of transactions vs. limit orders, over all, the null is rejected at the 5% level for 92.7% of all the stocks for bid changes, 66.1% of the stocks for bid depth. For the market orders vs. limit orders test

[33] The null is not rejected for decile 3. For the bid changes in decile 8 the p-value is 0.03.

[34] Even for the forth decile the average number of limit orders + market orders for each stock is more than 2000, enabling us to get a reasonable estimate of the population frequencies.

Table 4: Bid, with control for $\frac{\textbf{transaction (order) size}}{\textbf{quoted depth}}$[a]

	Transaction vs. Limit		Market vs. Limit	
Decile	≤quoted depth [b]	> quoted depth[c]	≤quoted depth	> quoted depth
Active	0.00 [d] (5923)	0.00 (714)	0.00 (5104)	0.00 (513)
2	0.00 (2916)	0.00 (645)	0.00 (1907)	0.00 (411)
3	0.00 (2224)	0.00 (748)	0.99 (1414)	0.00 (511)
4	0.00 (1383)	0.00 (587)	0.22 (866)	0.00 (391)
5	0.00 (1459)	0.00 (747)	0.98 (761)	0.00 (442)
6	0.00 (909)	0.00 (550)	0.29 (479)	0.00 (362)
7	0.00 (746)	0.00 (429)	0.48 (370)	0.00 (274)
8	0.00 (495)	0.00 (292)	0.99 (213)	0.00 (194)
9	0.00 (324)	0.00 (311)	0.99 (125)	0.00 (196)
Inactive	0.00 (88)	0.00 (92)	NA [e]	0.00 (56)
All	0.00 (16467)	0.00 (5115)	0.00 (11280)	0.00 (3350)

[a]We include the number of observations for the corresponding test in the parenthesis.

[b]Probability of the sample event under the null for bid changes for transactions (market orders) and limit orders of less than the prevailing quoted depth in size.

[c]Probability of the sample event under the null for the bid changes for transactions (market orders) and limit orders of larger than the prevailing quoted depth.

[d]More than 90% of 0.00's reported here are less than 10^{-3}.

[e]A NA appears if the number of observations for a test is less than 50.

Table 5a: Bid, limit orders vs. market orders which are executed against the book, with control for order size.[a]

	Market vs. Limit				
Decile	All	≤500 [b]	500-1500[c]	1500-5000[d]	>5000[e]
Active	0.00 [f] (5617)	0.00 (2812)	0.00 (1476)	0.00 (1107)	0.00 (222)
2	0.00 (2318)	0.00 (979)	0.00 (735)	0.00 (505)	0.00 (99)
3	0.18 (1925)	0.31 (979)	0.00 (550)	0.00 (350)	NA [g]
4	0.00 (1257)	0.29 (610)	0.00 (339)	0.00 (254)	0.02 (54)
5	0.00 (1203)	0.33 (509)	0.00 (410)	0.00 (242)	NA
6	0.00 (841)	0.00 (378)	0.00 (299)	0.00 (144)	NA
7	0.00 (644)	0.20 (259)	0.00 (229)	0.00 (145)	NA
8	0.03 (407)	0.90 (129)	0.00 (160)	0.00 (102)	NA
9	0.00 (321)	0.09 (123)	0.00 (111)	0.00 (75)	NA
Inactive	0.10 (97)	NA	NA	NA	NA
All	0.00 (14630)	0.00 (6810)	0.00 (4341)	0.00 (2945)	0.00 (534)

[a] We include the number of observations for the corresponding test in the parenthesis.

[b] Probability of the sample event under the null for the bid changes for market orders and limit orders of at most 500 shares.

[c] Probability of the sample event under the null for the bid changes for market orders and limit orders of more than 500 shares and at most 1500 shares.

[d] Probability of the sample event under the null for the bid changes for market orders and limit orders of more than 1500 shares and at most 5000 shares.

[e] Probability of the sample event under the null for the bid changes for market orders and limit orders of more than 500 shares.

[f] More than 90% of 0.00's reported here are less than 10^{-3}.

[g] A NA appears if the number of observations for a test is less than 50.

Table 5b: Bid Depth, Limit orders vs. market orders which are executed against the book, with control for order size.[a]

	Market vs. Limit				
Decile	All	≤500 [b]	500-1500[c]	1500-5000[d]	>5000[e]
Active	0.00 [f] (14335)	0.00 (7334)	0.00 (3524)	0.00 (2761)	0.26 (716)
2	0.00 (6353)	0.00 (2538)	0.00 (2033)	0.00 (1521)	0.02 (261)
3	0.16 (3759)	0.00 (1972)	0.00 (1017)	0.00 (680)	0.00 (90)
4	0.00 (3340)	0.00 (1518)	0.00 (865)	0.00 (727)	0.75 (230)
5	0.00 (2779)	0.00 (1267)	0.00 (815)	0.00 (559)	0.34 (138)
6	0.00 (1872)	0.00 (873)	0.00 (583)	0.00 (350)	0.78 (66)
7	0.00 (1408)	0.00 (542)	0.00 (491)	0.00 (335)	NA [g]
8	0.00 (1121)	0.00 (477)	0.00 (374)	0.00 (221)	NA
9	0.00 (679)	0.00 (301)	0.00 (212)	0.00 (142)	NA
Inactive	0.00 (211)	0.00 (72)	0.00 (62)	0.00 (51)	NA
All	0.00 (35857)	0.00 (16894)	0.00 (9976)	0.00 (7347)	0.93 (1640)

[a] We include the number of observations for the corresponding test in the parenthesis

[b] Probability of the sample event under the null for the bid depth changes for market orders and limit orders of at most 500 shares.

[c] Probability of the sample event under the null for the bid depth changes for market orders and limit orders of more than 500 shares and at most 1500 shares.

[d] Probability of the sample event under the null for the bid depth changes for market orders and limit orders of more than 1500 shares and at most 5000 shares.

[e] Probability of the sample event under the null for the bid depth changes for market orders and limit orders of more than 500 shares.

[f] More than 90% of 0.00's reported here are less than 10^{-3}

[g] A NA appears if the number of observations for a test is less than 50.

the percentages of rejections are 67.2%, and 61.0% respectively. In addition to reporting the percentage of stocks for which the null is rejected, Table 6 also records (in parentheses) the percentage of stocks that satisfy Definition 2 (i.e., the percentage of stocks that the ratio $\frac{\text{quote changes attributed to transactions/market orders}}{\text{transactions/market orders}}$ is greater than the ratio $\frac{\text{quote changes attributed to limit orders}}{\text{limit orders}}$). When we compare transactions vs. limit orders, the relevant percentages are 98.1% and 81.3%. For the market order vs. limit order test the corresponding percentages are 81.8% and 72.8%. Furthermore, when we test transactions vs. limit orders the percentage of rejections for bid changes is uniformly larger (decile by decile) than the percentage of rejections for the bid depth changes. Thus, when compared to transactions, limit orders are more important in affecting the specialist's bid depth than they are in affecting the bid.[35] This is consistent with a situation in which the price variables (i.e., bid and ask) are set to reflect the value of the underlying security whereas the depth is set such that on one hand it reflects the open interest (at the prevailing price) and on the other hand it helps the specialist control her inventory position. For market orders, the percentage of rejections does not differ so much for bid and bid depth. Furthermore, for small transaction/order sizes (up to 500 shares) the relative difference between transactions/market orders and limit orders is less pronounced than it is for larger transactions/orders. The private information, if any, that is conveyed by small transactions/orders is probably negligible. Moreover, the effect of a small transaction on a specialist's inventory position is also minor.

Table 6 also allows us to indirectly compare the effect of transactions vs. market orders on a specialist's quote updating process. When comparing the percentage of rejections under the two tests, it can be seen that, except for decile 1 for the bid depth variable, the percentage of rejections when testing transactions vs. limit orders is uniformly higher than that obtained when comparing market orders to limit orders.[36] In order to further investigate this issue we use the methodology developed in this paper to compare between transactions which are not against a market order vs. transactions which are against a market order. When including both non NYSE and NYSE transactions we obtain that transactions not against market orders are significantly more important (p-value less than

[35]This result is consistent with Kavajecz (1995) where it is shown that a specialist uses her knowledge of the limit order book when setting depths.

[36]The differences for bid depth changes seem to be smaller than those for bid changes.

Table 6a: Bid, stock by stock, with control for size [a]

		Transaction vs. Limit			Market vs. Limit		
Decile[b]	N[c]	All [d]	<=500[e]	>500[f]	All	<=500	>500
Active	15	93.3	60.0	100.0	86.6	80.0	86.6
		(100.0)	(100.0)	(100.0)	(93.3)	(100.0)	(93.3)
2	14	92.8	78.5	100.0	78.5	57.1	78.5
		(100.0)	(100.0)	(100.0)	(85.7)	(100.0)	(92.8)
3	15	93.3	60.0	100.0	26.6	20.0	93.3
		(93.3)	(93.3)	(100.0)	(60.0)	(73.3)	(100.0)
4	11	90.9	45.4	100.0	81.8	45.4	100.0
		(100.0)	(90.9)	(100.0)	(90.9)	(72.7)	(100.0)
All	55	92.7	61.8	100.0	67.2	50.9	89.0
		(98.1)	(96.3)	(100.0)	(81.8)	(87.2)	(96.3)

Table 6b: Bid Depth, stock by stock, with control for size

		Transaction vs. Limit			Market vs. Limit		
Decile	N	All	<=500	>500	All	<=500	>500
Active	15	86.6	86.6	100.0	93.3	100.0	93.3
		(86.6)	(100.0)	(100.0)	(93.3)	(100.0)	(93.3)
2	15	73.3	86.6	100.0	66.6	93.3	93.3
		(80.0)	(93.3)	(100.0)	(80.0)	(100.0)	(100.0)
3	15	46.6	40.0	100.0	33.3	33.3	60.0
		(73.3)	(73.3)	(100.0)	(46.6)	(80.0)	(93.3)
4	14	57.1	35.7	100.0	50.0	42.8	71.4
		(85.7)	(85.7)	(100.0)	(71.4)	(78.5)	(100.0)
All	59	66.1	62.7	100.0	61.0	67.7	79.6
		(81.3)	(88.1)	(100.0)	(72.8)	(89.8)	(96.6)

[a] In order to be included in this table a stock has to have at least 50 observations in every test of this table. In parenthesis, we include the percentage of stocks for which the ratio of the LHS to the RHS of the inequality in Definition 1 of Section 2 is greater than 1.

[b] The stocks are sorted according to activity (15 in each of the first four deciles and 14 in each of the last six). Activity is defined as the total number, over all 63 trading days, of transactions + limit orders.

[c] Number of stocks in a decile.

[d] Percentage of rejections of the null for bid (depth) changes at the 5% level.

[e] Percentage of rejections of the null for bid (depth) changes at the 5% level when transactions (market orders) and limit orders are of at most 500 shares in size.

[f] Percentage of rejections of the null for bid (depth) changes at the 5% level when transactions (market orders) and limit orders are of more than 500 shares in size .

0.01) for the bid and the ask changes, but are not able to reject equal importance for bid depth and ask depth changes. When restricting to NYSE transactions, we obtain that transactions not against market orders are significantly more important (p-value less than 0.01) than transactions which were executed against market orders for both price and depth variables. One part of the transactions originate in the upstairs market. These transactions in general convey more private information than transactions in the downstairs market. Another part of transactions are those undertaken by floor brokers. The specialist observes how eager the floor broker is to transact and at what prices. Thus, for trades in which one of the participants is a floor broker the specialist is probably able to extract more information.

4.4 Economic significance

In order to demonstrate that the differences in importance that we identified are not only statistically significant but also economically significant, in Table 7 we report the conditional probabilities of observing a bid change after observing a limit order, a limit order submitted at the touch or better, a market order, an NYSE transaction and a non NYSE transaction. The results for bid size, ask and ask size changes exhibit similar differences in magnitude between the different categories. Over all the sample, the probability of observing a bid change after a market order is 6% larger than that of observing a bid change after a limit order and 5% larger than after a submission of a limit order that is submitted at the touch or better. The ratio of the conditional probabilities, over the whole sample, of observing a bid change after a limit order to that of observing a bid change after a market order is around 60%. The differences are more pronounced for the inactive stocks than for the active stocks. This is consistent with a situation in which for active stocks the specialist generally reflects the market and thus the order type has a small marginal effect on his quote changing decision. For less active stocks the specialist trades more on his own account and thus the differences between the different order types has a greater effect on his quote updating decision. The differences between limit orders and NYSE transactions are even greater. Over all the sample the difference is about 9% and the ratio of the conditional probabilities is around 50%. Thus, transactions and market orders are not only statistically more significant, but also economically more significant than limit orders in the specialists quote updating process.

Table 7: Conditional Probability of A Bid Change

Decile[a]	OBS	PBLMT [b]	PBLMT0 [c]	PBMKT [d]	PBT [e]	PBTN [f]
Active	15	0.028	0.029	0.050	0.057	0.034
2	15	0.035	0.040	0.061	0.087	0.039
3	15	0.051	0.059	0.078	0.113	0.052
4	15	0.053	0.060	0.084	0.118	0.055
5	14	0.077	0.089	0.136	0.179	0.058
6	14	0.076	0.088	0.154	0.194	0.064
7	14	0.088	0.097	0.165	0.207	0.067
8	14	0.095	0.109	0.168	0.219	0.108
9	14	0.130	0.149	0.242	0.287	0.131
Inactive	14	0.138	0.156	0.349	0.277	0.092
All	144	0.076	0.086	0.145	0.172	0.069

[a]The stocks are sorted according to activity (15 in each of the first four deciles and 14 in each of the last six). Activity is defined as the total number (over all 63 trading days) of transactions + limit orders.

[b]Average probability, across stocks, of a bid change conditional on a limit order submission.

[c]Average probability, across stocks, of a bid change conditional on a limit order submitted at or inside quote.

[d]Average probability, across stocks, of a bid change conditional on a market order submission.

[e]Average probability, across stocks, of a bid change conditional on an NYSE transaction.

[f]Average probability, across stocks, of a bid change conditional on an non-NYSE transaction.

5 Conclusion

This paper provides a simple nonparametric test of the relative importance of transactions vs. limit orders and market orders vs. limit orders in influencing a specialist's quote updating process. We find that both transactions and market orders are more important than limit orders in affecting the quote updates. This remains true even after controlling for size.

Furthermore we are able to establish that:

1. One of the reasons that market orders are more important than limit orders is that, in general, they convey more information about the value of the underlying security.

2. When comparing transactions vs. limit orders the differences are larger for price variables (i.e., bid and ask) than for depth variables (i.e, bid depth and ask depth).

3. When comparing (indirectly) the relative importance of transactions and market orders one finds that transactions are more important. Furthermore, the difference between transactions and market orders seems to be larger for the price variables (bid

and ask) than for the depth variables (bid depth and ask depth).

4. For small transaction/order sizes the relative difference between transactions/market orders vs. limit orders seems to be less pronounced.

5. A given activity affects inactively traded stocks more than active ones.

The above features should be part of the guidelines of constructing a comprehensive model of a specialist's quote updating process which incorporates transactions, market orders and limit orders.

References

Amihud, Y. and H. Mendelson, 1980, "Dealership market: Market making with inventory," *Journal of Financial Economics*, 8, 31-53.

Angel, J., 1992, "Limit orders versus market orders," working paper, Georgetown University.

Chakravarty, S. and C. Holden, 1995, "An integrated model of market and Limit orders," *Journal of Financial Intermediation*, 4, 213-241.

Easley, D., and M. O'Hara, 1991, "Order form and information in security markets," *Journal of Finance*, 47, 577-606.

Foucault, T., 1993, "Price formation in a dynamic limit order market," working paper, Group HEC.

Glosten, L., 1994, "Is the electronic open limit order book inevitable?," *Journal of Finance*, 49, 1127-1162.

Glosten, L. and P. Milgrom, 1985, "Bid, Ask, and transaction prices in a specialist market with heterogeneously informed agents," *Journal of Financial Economics*, 14, 71-100.

Harris, L., 1994, "Optimal dynamic order submission strategies in some stylized trading problems," working paper, University of Southern California.

Harris, L. and J. Hasbrouck, 1996, "Market vs. Limit orders: The superDOT evidence of order submission strategy," *Journal of Financial and Quantitative analysis*, 31, 213-233.

Hasbrouck, J., 1991, "Measuring the information content of stock trades," *Journal of Finance*, 46, 179-208.

Hasbrouck, J., 1992, "Using the TORQ database, working paper," New York University.

Hasbrouck, J. and G. Sofianos,1993, "The trades of market makers: an empirical analysis of NYSE specialists," *Journal of Finance*, 48, 1565-1593.

Hasbrouck, J. and D. Sosebee, 1992, "Orders, Trades, Reports and Quotes at the NYSE," working paper.

Ho, T. and R. Macris, 1984, "Dealer bid-ask quotes and transaction prices: an empirical study of AMEX options," *Journal of Finance*, 39, 23-45.

Ho, T. and H. Stoll, 1983, "Optimal dealer pricing under transactions and return uncertainty," *Journal of Financial Economics*, 9, 47-73.

Hong, H. and J.Wang, 1995, "Trading and returns under periodic market closures," working paper, MIT.

Green, W.H., 1993, *Econometric Analysis*, second edition, Macmillan Publishing Company.

Kavajecz, K., 1995, "A specialist's quote depth and the limit order book," working paper, Northwestern University.

Kenz, P.J,. and M.J., Ready, 1996, "Estimating the profits from trading strategies," *Review of Financial Studies*, forthcoming.

Kyle, A., 1985, "Continuous auctions and insider trading," *Econometrica*, 53, 1315-1335.

Madhavan, A. and S. Smidt, 1991, "A Bayesian model of intraday specialist pricing," *Journal of Financial Economics*, 30, 99-134.

Madhavan, A., 1993, "An analysis of changes in specialist inventories and quotations," *Journal of Finance* , 48, 1595-1628.

O'Hara, M. and G. Oldfield, 1986, "The microeconomics of market making," *Journal of Financial and Quantitative analysis*, 21, 361- 376.

Ready, J.M., 1996, "The specialist's discretion: stopped orders and price improvement," working paper, University of Wisconsin-Madison.

Rock, K., 1996, "The specialists order book and price anomalies," *Review of Financial Studies*, forthcoming.

Rubinstein, M., 1985, "Nonparametric tests of alternative option pricing models using all reported trades and quotes on the 30 most active CBOE option classes from August 23, 1976 through August 31, 1978," *Journal of Finance*, 40, 455-480.

Seppi, D., 1995, "Liquidity provision with limit orders and a strategic specialist," Working paper, Carnegie Mellon University.