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Consistency between Predicted and Actual Bid-Ask Quote-Revisions

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ABSTRACT

This paper employs a "transaction" data-base to study whether observed quote-revisions are consistent with those predicted by the adverse selection and inventory cost theories of the bid-ask spread. We find that actual quote-revisions are consistent with the theoretical prediction in only 25% of the cases. Furthermore, quote-revision patterns are found to be strongly dependent on the level of the outstanding spread and, to a lesser extent, on the transaction size. These systematic patterns, unrelated to the inventory cost and adverse selection theories, are consistent with the effect on quote-revisions of the limit order book and the minimum 1/8 price-change rule.

EMPIRICAL RESEARCH IN THE market-microstructure area is benefiting significantly from the introduction of time-series transaction data bases that also incorporate bid and ask quote information (see Hasbrouck and Ho (1987); Hasbrouck (1988); Harris (1989)). The purpose of this paper is to examine how well observed quote-revision patterns (on the NYSE) conform with the predictions of the dealer/specialist models of bid and ask prices. Posted bid-ask quotes may be for the specialist's own account or from the public limit-order book. Our analysis sheds light on the role of the limit book in influencing quote-revisions.

The logic of our analysis can be motivated by first highlighting our key empirical results. Dealer/specialist models of bid-ask quotes (see Stoll (1989) for a review) predict that *both* bid and ask prices should be revised downward (upward) following a transaction at the bid (ask). However, of a sample of 62,000 quote-revisions drawn from 250 NYSE firms over a 42-day period, only 23% fall into this category. Following a transaction at the bid (ask), it is far more common for neither price to be changed (40% of the cases) or only the bid (ask) price to be changed (27%). These proportions suggest that, in general, less than 25% of all quote-revisions are consistent with the predictions of the theoretical models.

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Our results also indicate that quote-revision patterns are strongly dependent on the level of the posted spread and, to a lesser extent, on the transaction size; these regularities are not predicted by the models. In particular, quote-revision patterns are strongly consistent with the models (i.e., both quotes being changed is the dominant type of quote-revision) when the posted bid-ask spread is $\geq 3/8$, but not at smaller spread levels. The impact of transaction size on choice of quote-revision is quite marked when the posted spread is $\leq 2/8$, but negligible at spreads $\geq 3/8$. These patterns hold across securities, independent of measures of firm-size, trading intensity, and security price-level.

Thus, the evidence suggests that quote-revisions are generally not consistent with the predictions of the dealer/specialist models. We argue here that these patterns may be explained, in part, by the role of the limit book and the fact that the minimum allowable price-change is 1/8. The results from this study may be helpful in estimating the relative proportions of liquidity contributed by the specialist and by public limit orders. Our analysis identifies situations in which there is a high probability that posted quotes are for the specialist's own account.[1] Identification of such subsamples would be useful in (i) tests of the relative importance of the two dominant microstructure theories (see Hasbrouck (1988)), and (ii) for assessment of specialist participation and performance and the specialist's realized versus quoted spread (see Stoll (1989)).[2] Our results may also have a bearing on event-studies using transaction data. For example, our results indicate that the "expected" or normal quote-midpoint change would be zero if the outstanding spread were 1/8 but nonzero if the spread level were 3/8.

Our paper is organized as follows. Section I provides a brief review of dealer/specialist models of market-making. Section II outlines how limit orders, the minimum 1/8 price-change rule, and other factors are likely to affect observed quote-revision patterns. The data are discussed in Section III. The results, employing a contingency-table analysis of quote-revision pat-

[1] Typical estimates of specialist participation, on an overall basis, range from 10–15% (NYSE Fact Books (1985, 1986, 1987); see also Schwartz (1988) and Gammill and Marsh (1988)). Stoll (1985) estimates the specialist participation rate to be about 24% and discusses the role of the limit-order book in narrowing the spread. It should be emphasized, however, that these are statistics at the aggregate level; clearly, there exist numerous situations where the specialist's participation is high. We attempt to identify such conditions. Klemkosky and Winkler (1985) specifically attempt to estimate the proportion of the time that quotes are provided by the specialist, given that quotes may be from the book. They relate specialist participation rates (obtained by surveying specialist units) to the spread and find a positive relationship. Overall, they conclude that "the specialist is not very important in determining the market spread available to investors." However, they use daily data.

Ketchum (1989) and Wood (1989) discuss how the importance of liquidity-provision by the specialist waned with the advent of block trading but has since regained because of basket trading and indexation.

[2] Hasbrouck points out that limit orders can obscure the specialist's inventory-control behavior, especially for high-volume stocks. Thus, it is useful to identify situations where the quotes are less likely to have originated from the limit book.

terns with respect to the spread level and transaction size, are presented in Section IV. Concluding comments are offered in Section V.

I. Quote-Revisions: Inventory Control and Adverse Selection Theories

The specialist is assumed to have an estimate of the true stock price and then set the bid and ask prices around the true price so as to cover his expected costs at least. Two types of costs that can vary over time are relevant for this study: (a) inventory holding costs—the specialist is obligated to hold a suboptimal portfolio at times (related to the price-risk of holding "unwanted" inventory) and (b) adverse selection costs—the expected trading loss to informed investors. The size of the spread is assumed to be limited by competitive forces (public limit orders, floor traders, etc.) and is reflected in a zero expected-profit condition.

These considerations also dictate how quotes may be revised. Following a transaction at the bid/ask, the specialist may change only the bid price, only the ask price, both bid and ask prices, or change neither; although the last is not strictly a quote-revision, we will refer to it as such. These four types of quote-revisions are hereafter referred to as "only bid changed", "only ask changed", "both changed", and "neither changed", respectively. Our paper deals with the pattern of choice among these four quote-revision types.

Suppose that a transaction takes place *at the bid* price (i.e., a specialist purchase). Both theories predict that, in general, *both the bid and the ask quotes will be revised* downward by equal amounts, leaving the size of the spread unchanged. Stoll (1989) provides a good description of the logic underlying this result. The downward revision of both prices occurs because: (i) in the inventory cost models (Stoll (1978); Ho and Stoll (1981)) the specialist wants to discourage further public sales and encourage public purchases and (ii) in the adverse selection models (Glosten and Milgrom (1986); Copeland and Galai (1983)) the bid and ask prices bracket the new, lower expected true value. The result that the spread size is unchanged obtains because: (i) the size of the spread is independent of the inventory level in the inventory cost models and (ii) the size of the spread is dictated by (exogenous) factors such as the perceived proportion of informed traders in the adverse selection models.[3] To put it another way, since the size of the spread is generally determined exogenously in these models, there is little reason for a single transaction to lead to a change in the spread size.

[3] O'Hara and Oldfield (1986) conclude that the spread size may depend on the inventory level. Stoll (1989) also points out that while the adverse selection model predicts that the bid and ask quotes are symmetric about the true price, this is not necessarily true in the inventory cost model. With respect to the adverse selection model, it is unlikely that a transaction taken at random would signal an increase in the proportion of informed traders. These models (e.g., Glosten and Milgrom) also restrict the trade size to unity, so that transaction size is not allowed to convey information.

Thus, both theories predict that a majority of quote-revisions subsequent to a transaction should fall into the "both changed" category. Such a finding would constitute prima facie evidence in support of the theories. However, finding that some other type of quote-revision dominates need not mean that inventory and/or adverse selection costs are unimportant or absent; it could be that certain assumptions made in the development of the theories are violated in practice. In particular, the theories generally assume that (i) the posted quotes are always for the specialist's own account and (ii) quotes can be adjusted in continuous dollar amounts. In practice, posted quotes could also be from the public limit order book, and the minimum allowable price-change is 1/8 of a dollar on the NYSE. While these assumptions are far from crucial to the economic logic of the theories, their violation can obscure empirical validation of the theories.

II. Factors Affecting the Frequency of Quote-Revision Type

This section describes the factors that give rise to observed quote-revision patterns different from those predicted by dealer market-making theories.

A. Minimum 1/8 Rule

Assume that the outstanding quotes are for the specialist's own account. Suppose that a particular transaction is seen by the specialist as having a small impact, in terms of information conveyed or effect on inventory. In that case, the specialist may feel that a full 1/8 change is not warranted and therefore revise neither the bid nor the ask. Thus, ceteris paribus, the 1/8 tick limitation would reduce the frequency of quote-revision. That is, there would be a greater frequency of "neither changed" and a smaller frequency of "both changed" than otherwise. As noted below, transaction size may moderate this effect.

B. Limit Orders on the Book

Suppose that posted quotes are always from the limit-order book, and the specialist functions merely as an order processor (does not post his own quotes). Following a transaction at the *outstanding bid* (a market order to sell), the subsequent quote-revision will depend on the volume of limit orders at that bid price (the breadth of the book). If the book is broad (large limit volume) relative to the transaction size, bid and ask prices will remain unchanged. If the transaction size is greater than the breadth, the next lower limit bid price will become the new bid price. The ask price, in general, will remain unchanged. Hence, quote-revisions will fall into the "neither changed" or "only bid changed" categories. High observed frequencies of these two

types of quote-revisions would be consistent with posted quotes emanating from the limit book rather than from the specialist's account.

Note, however, that because of the minimum 1/8 rule a high frequency of "neither changed" may also arise when quotes are from the specialist's own account. Thus, in situations exhibiting high frequencies of "neither changed", it is difficult to distinguish whether quotes are from the limit book or from the specialist's own account.

C. Transaction Price (Type)

Under the models, quote-revision patterns following a transaction at the bid are expected to be a "mirror" image of those following a transaction at the ask. The data make it possible to test whether this symmetry exists in fact.

D. Transaction Size

Other things equal, a larger transaction is likely to have a greater impact on the specialist's inventory or the limit order book and may also be assigned a higher probability of being "information-motivated". [4]

If the outstanding quotes are from the specialist's own account, a large transaction is more likely to elicit a quote-revision than is a small transaction. A smaller transaction would demand a smaller revision in the true price because of smaller impact on the specialist's inventory and/or lower information content; the 1/8 minimum may pose a threshold, resulting in no revision at all. As a result, the frequency of "neither changed" should decrease with increasing transaction size, with an offsetting increase in the frequency of "both changed".

If the outstanding quotes are from the limit book, a large transaction is more likely to exceed the prevailing breadth than a small transaction. Thus, large transactions should be associated with a lower frequency of "neither changed", with an offsetting increase in one-sided quote-revisions (i.e., "only bid changed" and "only ask changed").

These predicted differences in substitution patterns (between quote-revision types) as a result of transaction size may therefore provide a means of distinguishing whether quotes are from the book or from the specialist.

[4] Mildenstein and Schleef (1983) obtain the result that the spread size is positively related to the order size. Easley and O'Hara (1988) argue that an informed trader would like to trade a larger quantity. However, in a multiperiod world, strategic considerations may indicate that it is optimal for the informed trader to trade piecemeal or to camouflage himself with other large trades (see Kyle (1985) and Admati and Pfleiderer (1988)). The literature on the choice between limit versus market orders (reviewed in Cohen et al. (1986); see also Conroy and Winkler (1986); Kyle (1985); Jang and Jun (1988); and Rock (1988)) also considers these questions. Hasbrouck (1988) concludes that large trades convey more information than small trades. See Amihud et al. (1985) for an overview of the literature.

E. Level of the Outstanding Spread

In transaction-time, the posted spread varies substantially. The level of the spread at a given time, in addition to being based on fundamental factors (such as expected holding period or anticipated price-risk), may also indicate the likelihood of the posted quotes being from the limit book versus the specialist's own account. When other liquidity-providers such as public limit orders and floor brokers are relatively inactive or disinclined to participate (e.g., preceding an announcement), the specialist posts his own quotes, and the spread may be higher than normal. Conversely, when other liquidity-providers are active, the specialist's dealership function becomes less important. In short, high spreads imply a greater probability that quotes are for the specialist's own account and vice versa. If this conjecture is correct, quote-revisions at high spreads should be more consistent with theoretical predictions, and conversely.

F. Errors in Quotes

The quote-revision process may also depend on whether or not a particular spread is in error. For example, it is possible that some spreads, particularly large ones, are stale or were simply set incorrectly. The subsequent spread revision, therefore, requires a narrowing of the spread, which may entail that only the bid or the ask is changed, contrary to the predictions of the theories.

III. Data and Sample Characteristics

A. Data

The data tape was obtained from AMEX and contains quote and transaction records for all NYSE stocks for the months of March and April 1985 (42 trading days). Hasbrouck (1988) provides an excellent description of how the data was compiled. The quote records provide the bid and ask prices along with the time the quote was made. Transaction records include the transaction price, number of shares traded, and the time of the transaction. The present analysis includes the first 250 firms that have data for all 42 days.

The times provided are unique only up to 30-second intervals; that is, there may be more than one record (transaction or quote) with the same time-stamp. This happens because the tape shifts to a new time-stamp only every 30 seconds. Hence, if a transaction and quote carry the same time-stamp, it is not obvious whether the transaction preceded or followed that quote. We, therefore, adopted the following procedure for transaction records whose time-stamps coincided with that of a quote record. If the transaction takes place at or between the previous bid and ask prices, the transaction is assumed to have taken place prior to the current/revised quote. Otherwise, the transaction is assumed to take place after the current quote. Of the 370,846 transactions (associated with 264,679 quotes) included in the initial analysis, 147,837 transactions have the same time-stamp as a quote. Our

procedure assigns 144,106 of these transactions as being prior to the current quote (i.e., at the previous quotes) and 1,798 as being at the current quotes.[5]

The data were checked for data-entry errors. Observations for which the bid-ask spread was nonpositive or greater than \$5.00 were deleted. These were extremely few and mostly occurred on very active days for actively traded stocks.[6]

B. Sample Characteristics

The trading and quote-revision activity on a typical day can be quite different across firms. To gain some appreciation for the typical values and the cross-sectional variations, we consider several variables which reflect different aspects of trading and quote-revision activity. Some of the variables are summarized on a per day basis while others are summarized on a per transaction basis. The actual computational steps are as follows.

First, for each firm we compute the median value of each variable. For transaction-variables, this median is simply the median across all transactions for that firm; similarly, for quote-variables, it is across all quotes for that firm. For daily variables, we first obtain the median across all observations for each day. This gives forty-two observations for that variable; the median of these forty-two observations is used as the representative value of that variable for that firm. At the end of this step, we have a representative value of each variable for each firm. Table I presents the summary statistics from the cross-sectional (across firms) distributions of the representative values of the variables for the 250 firms included in the subsequent analysis. Comparing Table I to a similar table generated for the entire population of NYSE firms on the tape indicates that this sample is representative of the population.

[5] These figures, in conjunction with the fact that the time elapsed between quote-revisions is substantial (see Table I), suggest that transactions trigger quote-revisions and not the other way around. This justifies Hasbrouck's (1988) view that these are data errors and the assignment of all such transactions as being prior to the current quote. However, the procedure is necessarily ambiguous for cases involving two quotes and one transaction *all within one clock minute.* Our procedure will tend to put the transaction in between the two quote observations, whereas it might actually be the last in the sequence. Such instances are expected to be quite rare for the reason noted above. There are also a few occasions when we observe quote-revisions (generally spread decreases) without any intervening transactions. These occurrences are more frequent for thinly traded stocks and may arise from new limit orders or the specialist's efforts to elicit more transactions.

[6] A limitation, arising from the procedure for handling and recording the data, should be noted. On occasion, it is possible that a single order is executed in separate chunks which are recorded as separate transactions. We analyze separately the cases of a single transaction between quote-revisions and those of multiple transactions (the implicit assumption being that the multiple transactions originate from different orders). Under the recording procedure in use, what are recorded as multiple transactions may sometimes originate from a single order (which we would prefer to treat as a single transaction). *Only* the results pertaining to a *single* transaction between quote-revisions are discussed here.

Table I

Sample Characteristics

The table gives the cross-sectional distribution of the "representative" values of several variables. For a given firm, the representative value for variables based on transactions and quote-revision is simply the median value of that variable across all transactions and quote-revision, respectively. For the daily variables, a median is computed for each day, across all observations for that day; this yields 42 daily observations, and the median of this is used as the representative value.

	10th Percentile	Median	90th Percentile	Mean	Std. Dev.
Daily					
Volume/Day (100's of shares)	62	179	1546	489	760
Volume/Shares Outst., (in %)	0.011	0.080	0.634	0.23	0.39
No. of Transacs./Day	5	17	80	32	38
No. of Quotes/Day	5	13	45	22	25
No. of Block Trades/Day[a]	0	0	3	0.93	1.77
No. of Spread Changes/Day	2	7	25	12	16
No. of Large Spread Changes/Day[b]	0	0	3	1.31	7.9
Price Variability[c]	0.87	1.53	2.78	1.79	1.19
Transaction Basis					
Volume/Transaction, (100 shares)	2	3	6	4.0	2.0
Time between Transactions (secs.)	120	540	1620	722	618
Quote-Revision Basis					
Time between Quote-Revisions	180	630	1902	921	983
Other					
Dollar Spread	0.125	0.250	0.375	0.252	0.096
Percent Spread	0.51	1.08	2.34	1.37	1.18
Stock Price	8.43	23.63	50.48	27.4	31.4

[a] A transaction exceeding 10,000 shares is defined as a block trade.

[b] A large spread change is one where the spread changes by more than 0.250 from quote-revision to quote-revision.

[c] This uses the intraday high and low prices and is defined as (High−Low) * 200/(High + Low).

IV. Results

The data are classified in the following hierarchical order: first, by transaction price (at bid or ask), then by the level of the outstanding spread (1/8, 2/8, etc.), and finally by the transaction size. The results are presented in a contingency-table format with respect to these variables. The cell entries give the number of observations and this figure as a proportion of the associated column total.

A. Quote-Revision Patterns Conditional on Spread Level

Tables II and III provide the results following a transaction at the bid and the ask, respectively. The results are symmetric with respect to each other and yield identical conclusions.

Examination of the row totals for each quote-revision type leads to our first important conclusion: the proportion of "both changed" is less than 25%,

indicating that more than 75% of observed quote-revisions are inconsistent with the basic prediction of the dealer/specialist models.

The column labelled "Total" in Panel A of Tables II and III contains the basic results. They indicate quite clearly that quote-revision behavior is strongly dependent on the level of the outstanding spread. First and foremost, the frequency of "both changed" is quite high (greater than 70%) at spread levels $\geq 3/8$ and quite low when the spread is $\leq 2/8$ (about 7% when it is 1/8 and 25% at 2/8). Thus, quote-revisions are consistent with the models and with quotes being for the specialist's own account when the posted spread is 3/8 or greater, but not otherwise. Quote-revision behavior at spreads $\leq 2/8$ (high frequencies of "neither changed" and one-sided quote-revisions, i.e., "only bid/ask changed") is consistent with quotes being from the limit book but also consistent with the specialist posting quotes for his own account and being "inhibited" by the minimum 1/8 rule. It is worth noting that the spread is $\geq 3/8$ for only about 15% of the observations.

Panel B of the tables indicates the patterns in spread changes. The spread size is generally left unchanged during quote-revisions since the "no change (in spread)" proportion is around 60% at each spread level. However, if the spread is presently $\geq 3/8$, the spread is much more likely to be decreased on the next quote-revision than to be increased. For example, at a spread of 3/8, the "spread decrease" proportion is 32% while the "spread increase" proportion is only 11%. This active, voluntary move to narrow the spread reinforces the conclusion that posted quotes at spreads $\geq 3/8$ are likely to be for the specialist's own account. The specialist may choose to narrow the spread because the transaction has resolved some uncertainty, or in order to satisfy exchange obligations. By contrast, when the spread is 2/8, spread increases are much more likely than spread decreases (33% versus 13%, respectively). Such a spread increase would result if the transaction size exceeds the limit order breadth at that price, leading to a one-sided quote-revision. This is consistent with quotes at spreads of 2/8 generally being from the limit book rather than for the specialist's account.

B. Quote-Revisions Conditional on Transaction Size

The dependence of quote-revisions on transaction size may allow us to ascertain whether quotes are from the limit book or for the specialist's account. These results are presented in Panel A of Tables II and III under the heading "Transaction Size." A large transaction is defined as one which is greater than 1.5 times the normal transaction size.

To begin with, observe that the column totals indicate that the relative frequency of small/medium transactions to large transactions is generally about 2:1 and, importantly, is roughly the same *at every spread level.*[7] The constancy of this ratio suggests that differences in transaction size across

[7] Small/medium transactions and large transactions are not expected to occur with equal frequency, because a transaction is defined as large only if it is 1.5 (rather than, say, 1) times the normal value. Hence the relative frequency of small/medium to large transactions is roughly 2:1.

Table II

The Impact of Transaction Type, Spread Level, and Size on Subsequent Quote Revisions

The table provides data on the nature of quote revisions that follow a single transaction *AT THE OUTSTANDING BID*. The data are segregated by the level of the outstanding spread and transaction size.

Panel A: The cell entries give the number of observations and, in parentheses, this figure expressed as a percentage of the corresponding column total.

Level of Spread	Spread = 1/8			Spread = 2/8			Spread = 3/8			Spread > 3/8			
	Transaction Size			Transaction Size			Transaction Size			Transaction Size			
Quote Revision	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	ROW TOTAL
Only Bid Changed	2632 (27)	2372 (52)	5004 (35)	2085 (26)	1251 (34)	3336 (29)	104 (4)	40 (3)	144 (4)	65 (10)	32 (8)	97 (10)	8581 (27)
Only Ask Changed	231 (2)	83 (1)	314 (2)	999 (12)	255 (6)	1254 (11)	711 (27)	186 (15)	897 (24)	99 (15)	31 (8)	130 (13)	2595 (8)
Both Changed	514 (5)	410 (9)	924 (7)	1562 (19)	1376 (37)	2938 (25)	1636 (64)	949 (78)	2595 (69)	445 (69)	296 (79)	741 (73)	7188 (23)
Neither Changed	6325 (65)	1665 (36)	7990 (56)	3357 (41)	787 (21)	4144 (36)	102 (3)	33 (2)	135 (4)	27 (4)	15 (4)	42 (4)	12311 (40)
COLUMN TOTAL	9702	4530	14232	8003	3669	11672	2553	1208	3761	636	374	1010	30675

Panel B: The cell entries give the proportion (percent) of quote-revision resulting in spread increase, decrease and no change. These are aggregate data across all quote-revision types.

Level of Spread	Spread = 1/8			Spread = 2/8			Spread = 3/8			Spread > 3/8			
Change in Spread	Transaction Size			Transaction Size			Transaction Size			Transaction Size			
	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	ROW TOTAL
Increase	31	57	40	29	40	33	11	12	11	16	15	16	32
Decrease	0	0	0	14	9	13	34	28	32	38	46	41	10
No Change	69	43	60	56	51	54	55	59	57	46	38	43	58

[a] A "small to medium" transaction is defined as one whose relative size is less than or equal to 1.5. A "large" transaction is defined as one whose relative size is greater than 1.5. The relative size is defined as Transaction Size/"Normal" Transaction Size.

Table III

The Impact of Transaction Type, Spread Level, and Size on Subsequent Quote Revisions

The table provides data on the nature of quote revisions that follow a single transaction *AT THE OUTSTANDING ASK*. The data are segregated by the level of the outstanding spread and transaction size.

Panel A: The cell entries give the number of observations and, in parentheses, this figure expressed as a percentage of the corresponding column total.

Level of Spread	Spread = 1/8			Spread = 2/8			Spread = 3/8			Spread > 3/8			
	Transaction Size			Transaction Size			Transaction Size			Transaction Size			
Quote Revision	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	ROW TOTAL
Only Bid Changed	228 (2)	71 (1)	299 (2)	860 (11)	264 (7)	1124 (10)	637 (25)	140 (12)	777 (22)	82 (13)	29 (9)	111 (12)	2311 (7)
Only Ask Changed	2448 (24)	2617 (54)	5065 (34)	1944 (25)	1161 (31)	3105 (27)	68 (2)	31 (2)	99 (3)	59 (9)	23 (7)	82 (9)	8351 (27)
Both Changed	492 (4)	382 (7)	874 (6)	1491 (19)	1548 (41)	3039 (27)	1670 (67)	893 (81)	2563 (72)	439 (72)	243 (79)	682 (75)	7158 (23)
Neither Changed	6820 (68)	1753 (36)	8573 (58)	3333 (43)	744 (20)	4077 (36)	92 (3)	33 (3)	125 (4)	26 (4)	10 (3)	36 (4)	12811 (41)
COLUMN TOTAL	9988	4823	14811	7628	3717	11345	2467	1097	3564	605	305	910	30361

Panel B: The cell entries give the proportion (percent) of quote-revision resulting in spread increase, decrease, and no change. These are aggregate data across all quote-revision types.

Level of Spread	Spread = 1/8			Spread = 2/8			Spread = 3/8			Spread > 3/8			
Change in Spread	Transaction Size			Transaction Size			Transaction Size			Transaction Size			
	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	Small to Medium[a]	Large	Total	ROW TOTAL
Increase	29	59	38	28	37	31	9	10	9	11	9	10	32
Decrease	0	0	0	13	9	12	33	30	32	41	44	42	9
No Change	71	41	62	59	54	57	58	60	59	48	47	48	59

[a] A "small to medium" transaction is defined as one whose relative size is less than or equal to 1.5. A "large" transaction is defined as one whose relative size is greater than 1.5. The relative size is defined as Transaction Size/"Normal" Transaction Size.

spread levels could not have been responsible for the dependence of quote-revision behavior on the spread level. Another implication is that trader's choice of transaction size does not appear to be influenced by the level of the outstanding spread. A priori, the higher cost of liquidity/immediacy to traders implied by a larger spread (other things equal) would lead one to expect lower aggregate trading and smaller transaction sizes at larger spread levels.

Transaction size has a significant effect on quote-revision choice at all spread levels, but is particularly striking at spreads $\leq 2/8$. Specifically:

(i) *At a spread of* $1/8$, as we move from small/medium to large transactions, the "neither changed" proportion is nearly halved, and this is almost exactly offset by a doubling of the "only bid changed" proportion. This 1:1 substitution reaffirms the earlier conclusion that quotes at 1/8 may be from the limit book. The frequency of "both changed" is quite small regardless of transaction size.

(ii) *At a spread level of* $2/8$, the effects are similar but less pronounced. Of interest is the result that some of the decrease in the frequency of "neither changed" following large transactions is offset by a significant increase in the "both changed" type. This is consistent with a greater proportion of quotes being for the specialist's account, compared to when the spread is 1/8.

(iii) *At spreads* $\geq 3/8$, the effect of transaction size is quite muted. There is a reduction in the proportion of "only ask changed" which is taken up by an increase in the "both changed." This corroborates the earlier conclusion that quotes at this spread level are likely to be for the specialist's own account.

The most interesting observation from the spread change data (Panel B) is that the proportion of spread increases is about the same for large or small/medium transactions, when the spread is 3/8. Assuming that quotes at 3/8 are indeed more likely to be for the specialist's own account (as concluded earlier), this finding suggests that larger transactions do not necessarily have a greater impact on the specialist on average. The 1/8 limitation and the unwillingness to post "too wide" a spread may partially account for this.

In sum, transaction size does affect the quote-revision type. The results are consistent with larger transactions having a greater impact on the limit book. However, larger transactions do not appear to have a greater impact on the specialist than small transactions on average. The results generally confirm the earlier conclusion that specialist participation is difficult to detect at spreads $\leq 2/8$, whereas quotes posted with spreads $\geq 3/8$ are quite likely to be for the specialist's own account.

Finally, we note that essentially similar quote-revision patterns were observed for subsamples of the securities, formed on the basis of security price-level, average dollar spread, and average daily trading volume. Thus, these patterns appear to hold across securities of different characteristics.

V. Conclusions

The principal objective of this paper was to examine the consistency between actual bid-ask quote-revisions and those predicted by the adverse selection and inventory cost theories. We find that observed quote-revisions are inconsistent with the theoretical predictions for more than 75% of the observations. Furthermore, quote-revision patterns are strongly dependent on the level of the outstanding spread and, to a lesser extent, on the transaction size. These systematic patterns which are unrelated to the theories, are consistent with quote-revisions being affected by the limit order book and the minimum 1/8 price-change rule. The analysis may assist in identifying conditions under which the specialist's participation is likely to be high. Such subsamples would be useful in validating microstructure theories and addressing issues such as specialist performance and profits.

REFERENCES

Admati, A. and P. Pfleiderer, 1988, A theory of intraday patterns: Volume and price volatility, *Review of Financial Studies* 1, 3-40.

Amihud, Y., T. Ho, and R. Schwartz, 1985, *Market Making and the Changing Structure of the Securities Industries* (Lexington Books, Lexington, MA).

Cohen, K., S. Maier, R. Schwartz, and D. Whitcomb, 1986, *The Microstructure of Securities Markets* (Prentice-Hall, New York).

Conroy, R. and R. Winkler, 1986, Market structure: The specialist as dealer and broker, *Journal of Banking and Finance* 10, 21-36.

Copeland, T. and D. Galai, 1983, Information effects on the bid-ask spread, *Journal of Finance* 38, 1457-1469.

Easley, D. and M. O'Hara, 1987, Price trade size and information in securities markets, *Journal of Financial Economics* 19, 69-90.

Gammill, J. and T. Marsh, 1988, Trading activity and price behavior in the stock and stock index futures markets in October 1987, *Journal of Economic Perspectives* 2, 25-44.

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

Harris, L., 1989, A day-end transaction price anomaly, *Journal of Financial and Quantitative Analysis* 29, 29-45.

Hasbrouck, J., 1988, Trades, quotes, inventories and information, *Journal of Financial Economics* 22, 229-252.

—— and T. Ho, 1987, Order arrival, quote behavior, and the return-generating process, *Journal of Finance* 42, 1035-1048.

Ho, T. and H. R. Stoll, 1981, Optimal dealer pricing under transactions and return uncertainty, *Journal of Financial Economics* 9, 47-73.

Jang, H. and B. H. Jun, 1988, Trader's optimal order placement strategies with limit and market orders, Working paper, University of Houston.

Ketchum, R., 1989, Reacting to current trends, in H. Lucas and R. Schwartz, eds.: *The Challenge of Information Technology for Securities Markets* (Dow Jones-Irwin, Homewood, IL).

Klemkosky, R. and R. Winkler, 1985, Competition and the cost of liquidity to investors, *Journal of Economics and Business* 37, 183-195.

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

Mildenstein, E. and H. Schleef, 1983, The optimal pricing policy of monopolistic marketmaker in the equity market, *Journal of Finance* 38, 218-231.

NYSE, 1985-1987, *Fact Books* (New York Stock Exchange, Inc.)

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

Rock, K., 1988, The role of the specialist's order book: A possible explanation for certain price anomalies, Working paper, Harvard University.

Schwartz, R., 1988, *Equity Markets: Structure, Trading and Performance* (Harper & Row, New York).

Stoll, H. R., 1978, The supply of dealer services in securities markets, *Journal of Finance* 33, 1133-1151.

——, 1985, The stock exchange specialist system: An economic analysis, Monograph Series in Finance and Economics, Salamon Brothers Center for Study of Financial Institutions, New York University.

——, 1989, Inferring the components of the bid-ask spread: Theory and empirical tests, *Journal of Finance* 44, 115-134.

Wood, R., 1989, Survival strategies for exchanges, in H. Lucas and R. Schwartz, eds.: *The Challenge of Information Technology for Securities Markets* (Dow Jones-Irwin, Homewood, IL).

——, T. McInish, and J. Ord, 1985, An investigation of transaction data for NYSE stocks, *Journal of Finance* 40, 723-741.