July 1994

Quote Revisions and The Quoted Size: An Empirical Analysis

Mitchell A. Petersen
Kellogg Graduate School of Management
Northwestern University

and

Steven Umlauf
Morgan Stanley

ABSTRACT

We examine the importance of the size quoted by the specialist in the adjustment of prices. The quoted size is the maximum trade size for which the posted quotes are guaranteed. We find that the impact of trades on subsequent quote revisions depends significantly on whether the trade size exceeds the quoted size. Although larger trades are followed by larger quote revisions, most of the variation in quote revisions is explained by whether the trade size exceeds the quoted size. Once it does, further increases in the trade size have no effect. Our results also indicate that only a fraction of trades move the quotes.

We thank Stewart Myers, Robert Pindyck, David Scharfstein, Chester Spatt, and Bob Wood.

Economists long have been interested in how prices are set in security markets. The most obvious way for information to be impounded into prices is through public announcements. However, as economists have begun to examine intraday price data, it is clear that many price movements are not associated with public news announcements. The very act of trading moves prices. The purpose of this paper is to advance our knowledge of the empirical relation between trades on the stock exchange and the subsequent quote revisions. Quote revisions arise in our data in response to transactions as the adverse selection and inventory literatures would suggest.

More than just measuring the magnitude of the quote revisions which follow trades, we document two characteristics of the relation between quote revisions and trades that are not present in prior work. First, the specialist quotes volume limits which represent the maximum trade size for which he guarantees his quoted prices. These limits are referred to as the quoted size. Although the quoted prices are not guaranteed for larger trades, we do observe larger trades in our data set. This observation raises the question of what role the quoted size plays in the quote setting process. We show that the quoted size that is posted along with the quoted prices have a pronounced effect on the subsequent quote revisions. Trades that exceed the quoted size are followed by a larger total quote revision. However, these trades have a significantly smaller marginal impact on the subsequent quote revisions. Second, prior work has found that the relation between trades and quote revisions is concave (Hasbrouck, 1988). We are able to show that this finding is due to the model being misspecified. When we account for the role of the quoted size, the concavity found in previous work largely disappears.

Our results also suggest that only a fraction of trades actually move prices. In our sample, quotes are revised only after 18 percent of the trades. Since prices must be quoted in eighths of a dollar, this is not surprising. Trades which would generate a small revision in the absence of this restriction generate zero revisions in the presence of this restriction. What is interesting is the way the quote revision is related to the trades which precede it. We find that the trade immediately preceding a quote revision is the only one that has a significant correlation with the quote revision. Trades which occurred earlier, but since the last quote revision, have no effect on the subsequent quote revision. This implies that the perceived information content of trades varies significantly. Trades either generate an immediate quote revision or none at all.

The next section describes the possible roles of the quoted size. In Section II we discuss the construction of our data set. We also highlight some of the potential econometric problems that we will need to confront. In Section III we present our initial results. We estimate the quote revision rule for 119 New York Stock Exchange issues. We find that trades do move quotes, but the form of the relation depends importantly on the size of the trade relative to the quoted size. Trades larger than the quoted size are followed by significantly larger quote revisions that are essentially uncorrelated with the trade size. Since we document new relations, demonstrating the robustness of our results is important. We do this in section IV. Our initial description of the quote revision rule is robust to changes in the sample and changes in the functional form of the relation. We conclude with a summary of our findings and their implications for the price discovery process.

I: Quote Revisions and the Purpose of the Quoted Size.

The specialist on the New York Stock Exchange (NYSE) stands ready to buy or sell stock at the prices he quotes. An extensive literature, both theoretical and empirical, focuses on the manner in which these prices are set. The theoretical market microstructure literature identifies two concerns of specialists -- inventory and adverse selection. The inventory literature argues that specialists will quote their spreads to eliminate deviations from preferred inventory levels. They will raise their quotes when they are short of their preferred inventory levels. This change will encourage traders to sell shares to the specialist (see Amihud and Mendelson (1980) and Ho and

Stoll (1981)). The adverse selection literature focuses on information asymmetries between the specialist and privately informed traders who possess knowledge of impending changes in the securities value. In these models, the specialist must charge a positive bid-ask spread to ensure that his expected profits are non-negative. Revisions in the quotes arise as information implicit in transactions is incorporated into prices. Purchases by public orders are followed by increases in the quotes because informed traders will buy shares when they believe the security is undervalued (see Easley and O'Hara (1987), Glosten and Milgrom (1985), Glosten (1989), and Kyle (1985)).

Since the specialist must post his quotes before the other traders disclose their demands, he risks trading losses with better informed traders. The specialist is committed to honor the quotes he posts. As the theoretical literature has argued, the specialist can set wider spreads to compensate for this risk, but he has another tool at his disposal. He can limit volume. The quotes posted by the specialist are valid for only a limited number of shares. Presumably the specialist uses the quoted sizes to prevent large losses in transactions with better informed traders or to prevent being stuck with a large block of stock in an illiquid market. We refer to these maximum volumes as the quoted size. The specialist quotes a size for both the bid and the ask side of the market.

Just as the posted quotes may represent public limit orders, as opposed to demand by the specialist, the quoted size may also represent public limit orders opposed to the specialist's demand. When posting the quoted volume, the specialist may quote less volume than is represented by his demand plus public limit orders (McInish and Wood (1992)). Floor traders will sometimes ask that the full size of their order not be revealed in the posted quotes. Since the specialist may not show the full amount of his or the limit order's demand, the true level of liquidity may exceed the quoted size.[1] The specialist is not required to accept more than the quoted size, but such trades do occur. In our sample the frequency of trades which exceed the quoted size ranges from 2.0 percent (Bankamerica Corporation) to 85.2 percent (American International Group, Inc.). For the median firm, 24 percent of the trades exceed the quoted size.

Empirically the quoted size is not the binding limit one might expect it to be. Its role in price adjustment, however, has not been examined. It is possible that the quoted size is an unimportant institutional detail. In that case, ignoring the quoted size in modeling quote revisions is correct. The quoted size, however, may contain important information about the liquidity available in the market. Since the quotes are valid for only a limited number of shares, liquidity may decline significantly once a trade size exceeds the quoted size. Traders can sell amounts up to the quoted size without affecting the transaction price of their trade. Trades larger than the quoted size may affect the transaction price of the trade. The specialist will buy more than the quoted size, for example, but only in exchange for a price concession. If the quoted size is correct, then there are no traders willing to buy more than the quoted size at the current bid. Trades which exhaust the available liquidity will, therefore, be followed by an immediate quote revision.

An alternative interpretation of trades larger than the quoted size is that these are trades by less informed individuals. The specialist posts a quote saying he is willing to purchase up to 2,000 shares at his bid. This limit protects him from a seller who has negative private information. At most the specialist will buy 2,000 shares at a price which is too high. The specialist may feel some sellers are less informed. He can relax the quoted size limit in these cases and purchase more than the specified 2,000. Floor traders who do not want their full order posted in the quotes may act in the same way. This sorting of orders means that trades which exceed the quoted size would contain less information. If this hypothesis is correct, then the quote revision following these trades will be smaller, controlling for the size of the order. This paper empirically examines the question of what role the quoted size plays in setting quotes.

II: Data and Econometric Specification

A: Construction of the Quote Revision Data Set

We construct a series of quote revisions and transaction volumes from the NYSE ticker tape for the thirty trading day period from September 1 to October 12, 1987. The original Institute for the Study of Security Markets (ISSM) database consists of chronological series of quoted and realized transaction prices and volumes. To obtain a sufficient number of observations to estimate a non-linear relation between trades and quote revisions, we wanted to restrict our sample to stocks with significant volume. We began with the first 125 companies in an alphabetical listing. From this original list we exclude six stocks for which fewer than 1000 observations were available in order to ensure sufficient samples sizes for estimation. Our final sample consisted of 119 stocks of firms with market values ranging from $18 million (Skyline Corporation) to $5 billion (General Electric). Trading frequencies of these stocks range from 22 to 518 trades per day.

Several modifications of the original ISSM data are necessary. We exclude regional exchange data because our focus is the NYSE. We drop opening transactions from our sample because the NYSE specialist opens each trading day with a call auction. Since we want to examine the effect of a trade on the following quote revision, each observation in our data set consists of a trade and the subsequent quote revision. The quotes are sometimes revised even though no intervening trade occurs. In such circumstances, we coded a zero volume trade between the two quotes. Since the volume variables equal zero, the intercept measures the average quote change in these cases. Some trades fail to induce a quote revision before the next trade. In these cases the existing quotes remain valid. We record the quote revision as zero following these trades.

We also exclude some observations from our data set. Some trades are executed at prices that lie within the quoted spread. We initially omit these trades from our sample, because we cannot confidently classify them as purchases or sales under plausible assumptions.[2] Many trades inside the spread are matched trades between public orders. Others involve the specialist. Occasionally the specialist will undercut his own quotes to capture trades (see Blume and Goldstein (1992)). We suspect that these trades have minimal information content. We examine the importance of these trades in Section IV. When we include these observations in our sample, our empirical findings do not change.

A small percentage of trades are executed at prices that lie outside the quoted spread. In our sample they constitute only 0.1 percent of the trades. We include these trades in our sample. Given the small number of trades, it is not surprising that when we excluded them the results were the same.

The ISSM data do not distinguish between buyer and seller initiated trades. We assume that transactions executed at ask are buyer initiated. We discuss the potential econometric problems arising from this classification method in the next section of our paper. We code trades at the ask as positive volumes and trades at the bid as negative volumes. We denominate volumes in thousands of shares and revisions in cents.

B: Potential Econometric Problems

A number of econometric concerns arise due to the limitations of our data. First, classifying ask trades as buyer initiated is incorrect when buyer initiated trades occur at the bid. The same problem arises when seller initiated trades occur at the ask. Misclassifications will pool sales with purchases and vice versa. Our estimates will average upward revisions induced by buyer initiated trades with downward revisions induced by seller initiated trades and thus reduce the magnitudes of quote revisions predicted by our regression model. The estimated coefficients will thus be smaller than the true coefficients. The magnitude of this bias will depend on the degree of misclassification in our sample. This problem is described more fully in the appendix.

To examine the validity of our trade classification rule we compared the frequency distributions of quote revisions induced by transactions we classify as purchases and sales. Figure 1 provides frequency distributions of quote revisions for all issues in our sample. Following trades we classify as buyer initiated, the quote change is positive 27 percent of the time. It is negative only 2 percent of the time. The results for trades we classify as seller initiated are similar. This is not absolute proof that our classification is correct. It does, however, indicate that the probability of misclassification is small. This figure also points out that the bid and ask are not always adjusted together. The midpoint of the quotes changes by a sixteenth, when only the bid or the ask are revised by an eighth. We examine independent movements in the bid and the ask in Section IV.

Our second concern arises because the ISSM data do not distinguish between trades in which the specialist participates as a dealer (buying for his own account) and as a broker (buying for an investor). [3] Recall that the theoretical literature suggests quote revisions arise due to adverse selection and inventory concerns. When the specialist does not participate in trades (e.g. a public limit order is hit) quote revisions will not depend upon the specialist's inventory. Since we cannot identify trades in which the specialist participates, our estimates will overestimate the adverse selection component of the quote revision rule. Our estimates will average quote revisions arising solely due to adverse selection with those arising due to both adverse selection and inventory control. If inventory costs are small, as Madhavan and Smidt (1991) suggest, the empirical significance of this averaging effect will be minimal.

If the specialist's inventory has an important effect on his quotes, then the specialists more frequent participation in small trades will make the estimated function between quote revisions and trade size more concave than the true function. The fact that we find almost no concavity in our quote revisions rules suggests that the inventory component of the quote revision is small. The details are described in the appendix.

C: Specification of the Quote Revision Rule

Since we are interested in how trades move the quotes on the stock exchange, the first step is to specify this relation empirically. We begin by specifying a regression equation where quote changes depend upon a quadratic function of the trade size. Thus in addition to the volume of the trade, we also include the sign of volume and volume squared.[4] Since we have coded buyer initiated trades as positive numbers and seller initiated trades as negative numbers, the sign of volume will be one for buys and minus one for sells. This coefficient is the expected quote revision for a zero volume buyer initiated trade. Initially the dependent variable is the change in the midpoint of the spread. In section IV, we examine changes in the bid and ask separately.

To investigate the role of quoted size, we estimate two quote revision functions. One is for trade sizes less than or equal to the quoted size and one is for trade sizes greater than the quoted size. If the quoted size is not a binding constraint, then the estimated slopes and intercepts should not depend on whether the quoted size is exceeded. The parameters of the two functions will not differ from each other in this case. If instead the quoted size is relaxed for trades from less informed traders, then quote revisions should be smaller when the quoted size is exceeded.

The NYSE requires prices to be quoted in even eighths of a dollar for each of the stocks in our sample. In the absence of price discreteness we would expect information to be continuously incorporated into the quotes. Each trade, regardless of the magnitude of its information content, would induce the specialist to revise his quotes. Trades with little information would induce small revisions. Discreteness, however, delays the incorporation of information into the quotes. The position of the spread is revised only when the optimal revision exceeds the minimum permissible change. When a revision is forgone, the desired revision accumulates. Observed quote revisions should thus depend on all transactions executed since the quotes were last revised. To account for discreteness, we include the sum of all trades since the last quote revision as an explanatory variable. This sum excludes the most recent trade, since it is included as a separate regressor. If the information content of trades is homogeneous, lagged volumes should induce quote revisions similar in magnitude to the trades that immediately precede quote revision.

We include two additional variables in the regression. First we interact the elapsed time since the last trade with the sign of volume. This is a control for trading frequency. We also include the change in the quoted size at the ask and the bid to control for the direct effect of the quoted size on the quotes.

III: The Quote Revision Rule and the Quoted Size.

A: Brunswick Corporation: An Example

For each of the 119 stocks in our sample we estimate the relation between revisions in the midpoint of the quotes and the trades that precede it. For concreteness, we start by describing the results for Brunswick Corporation. Although Brunswick is typical of the rest of the sample, we use it only as an illustration. The consistency of our results is confirmed by examining the entire sample.

Trades are correlated with quote changes. Trades which we classified as buyer initiated (trades at the ask) are followed by upward revisions in the quotes. Seller initiated trades are followed by downward revisions. Both the fact that a trade occurs and the actual size of the trade are important in predicting the subsequent quote revision. For example, a 1,000-share trade is followed by an average quote revision of 1.3 cents (see Table I). The average stock price for Brunswick is $23.55. Thus the percentage quote revision ranges from 0.03 percent for a 100 share trade to 0.08 percent for a 2,000-share trade.

The striking result from the Brunswick data is the difference between trades whose volume exceeds the quoted size compared to trades that do not. Both trades move the quotes in the expected direction, but their impact is quite different. For trades below the quoted size the quote revision depends upon both the type of trade, buy versus sell, as well as the size of the trade. Larger trades produce larger quote revisions. For Brunswick, each additional thousand shares increases the expected quote revision by about 0.62 cents, ignoring the quadratic term. For trades beyond the quoted size, the trade size has little effect on the size of the subsequent quote revision. If these trades are increased by 1,000 shares the quote revision increases by about 0.18 cents. The slope coefficient has dropped by seventy percent.

B: The Importance of the Quoted Size

Having described the results for one firm, we now look for similar relations in the entire sample. The relation between the quote revision and the preceding trades was estimated for the other 118 firms in our sample. For each stock we allow the relation between trades and quote revisions to differ for trades less than versus greater than the quoted size. For each coefficient we report the distribution of coefficients from the 119 regressions in Table II. We have divided each coefficient by the average stock price to make them comparable across stocks.

The distinction between trades above and below the quoted volumes is as striking in the full sample as it was for Brunswick Corporation. The two quote revision functions differ in two ways. First, the total quote revision is larger for trades that exceed the quoted volumes. Using the median coefficient estimates, we plot the two quote revision functions in Figure 2. For all volumes the quote revision following a trade is larger if it exceeds the quoted size. This finding is not consistent with these being less informed trades on average. The specialist or other market participants should be willing to relax their size limits and take these trades only if they expect these trades to come from relatively uninformed traders. The fact that following these trades the quote revisions are larger, not smaller, is inconsistent with this hypothesis. Market participants do not appear to be using the quoted size to sort traders into informed and uninformed groups. This result is not consistent with liquidity providers requiring price concessions to accept larger trades either. The price impact occurs after the trade is consummated at the current quote. Thus the price concession is just the spread and is not larger for these trades.

The second manner in which the quote revision functions differ is the marginal impact of larger trades. The large quote revision for trades above the quoted size is due mainly to the intercept term. For trades above the quoted size, the intercept component of the quote revision rule is almost three times as large --- .132 percent as opposed to .047 percent. Having the trade size exceed the quoted volume significantly raises the subsequent quote revision. However once the trade size exceeds this limit, additional increases are unimportant. The quote revision is almost independent of the trade size for this sample of trades. From Table II, the mean slope coefficient is only .003 percent, compared to a mean slope coefficient of .019 for trades below the quoted size. Even given the large number of observations we use, the slope coefficient for trades above the quoted size is statistically significant in less than half the sample.

Obviously the trades that exceed the quoted volume are larger on average than the trades that do not (860 shares as opposed to 5,200 shares). This raises the possibility that our findings are driven by non-linearities in the quote revision functions. This intuition is strengthened by the fact that prior work has found that the relation between quote revisions and trades is concave. Larger trades have progressively smaller marginal effect on the quotes (Hasbrouck, 1988). In fact the concavity arises only when the model is misspecified. The problem is that the role of the quoted size had not been addressed in prior work. Once we control for whether a trade exceeds the quoted size, the concavity in the quote revision rule largely disappears.

We do find some concavity in our estimates, but it is very slight. The quadratic coefficients are consistently statistically significant only for trades below the quoted size (see Table II). Even here the average t-statistic is only 2.16. For trades above the quoted size the coefficients are not statistically different from zero on average. More importantly, the magnitude of the concavity is tiny. Almost all of the coefficients are zero to three decimals (see Table II). Although we can make this claim by comparing the coefficients, a picture makes our point more clearly. We graph the two quote revision rules in Figure 2. It is clear that once the two separate functions are fit to the data, any remaining nonlinearity is minimal. The picture for Brunswick is similar. As a final statistical test, we estimated the model omitting the two quadratic terms. When these variables are omitted, the average R^2 drops from .246 to .243. The quadratic terms add little to the explanatory power of the model.

Employing quadratic terms also allows us to explore the possibility of coefficient bias arising due to the higher incidence of specialist participation in smaller trades. As discussed in Section II and the appendix, the specialists more frequent participation in small trades than large trades may introduce spurious concavity into the empirical relation between quote revisions and transaction volumes. The absence of substantial concavity is consistent with the inventory component of the specialist's quote revision rule being small.

The larger quote revisions for trades above the quoted size is consistent with less liquidity for these trades. This implies that the quoted size is a signal of the available liquidity. Trades beyond this level have a greater price impact. Based on the median estimates from Table II, we find that the average quote revision following a trade ranges from 0.06 percent of the quoted price for a 1000 share trade to 0.28 percent for a 40,000 share trade.[5] These figures are smaller than those estimated for block trades by Kraus and Stoll (1972) and Holthausen, Leftwich, and Mayer (1987). They resemble quite closely the .06 to .10 percent price impact figures reported by Chan and Lakonishok (1991). Our results attribute most of this change to increasing the trade size beyond the quoted volume. For example, a 2,000 share purchase would be followed by a .081 percent increase in the quotes, if the quoted size was greater than 2,000 shares. If the quoted size at the time the trade was executed was less than 2,000 shares, the trade would be followed by a .138 percent increase in the quotes on average.

C: Discrete Information and Lagged Trades

Since the quotes are not revised after each trade, previous trades may affect the subsequent quote revision. When the quotes are not revised after a trade, any information in that trade cannot yet have entered the quotes. We now turn to the question of how this information enters the quotes. In addition to the current trade, we include the trades since the last quote revision as an additional regressor. The coefficient on this variable should be of similar magnitude to the ones discussed above if the information content of trades, controlling for their size, is homogenous. In this case, as trade information accumulates, so will the desired quote change. When the desired quote change exceeds the minimum tick, the quotes will be raised or lowered. Statistically, the quote change will be correlated with all of the trades since the last quote revision.

Our results are not consistent with this hypothesis. We find that the lagged trades have only a small effect on the quote revisions (see Table III). The median coefficient is zero; the 95th percentile is only .004 percent. Only 28 percent of the coefficients are statistically different from zero at the one percent level.

These results indicate that the information content of trades is not homogenous. Some trades are perceived to contain information and the quotes are revised before the next trade. Other trades are perceived to have little or no information. Not only do these trades not induce an immediate quote revision, they never move the quotes. Recall that the quotes are altered only after eighteen percent of the trades. These results suggest that the other eighty-two percent of trades have little effect on the quotes. This finding is not due to the fact that prices are allowed to move only discretely. Discrete prices will mean the quotes are not revised after each trade. However, when we statistically allocate the quote revision to the preceding trades, we could still find that earlier trades influences the subsequent quote revision. We do not.

IV: The Robustness of the Role of Quoted Size

In this section we validate the results of the previous section by generalizing some of our initial assumptions and altering the sample used in the estimation procedure.

A: The Influence of Outliers.

The presence of outliers may alter the estimated form of the quote revision rule. To evaluate the robustness of our results, we estimate the quote revision functions on the center ninety percent of the volume distribution.[6] The volume coefficients are reported in Table IV. Qualitatively the coefficients show the same pattern as before. Quote revisions following trades that exceed the quoted size are significantly larger. The intercept component of the quote revision rule is .116 percent as opposed to .038 percent. The role of volume is less dramatic. In the previous results, once the trade size exceeded the quoted volume it had little effect on the subsequent quote revision. The coefficient on volume is smaller when the quoted size is exceeded, but the difference in magnitudes is no longer as large as before. If we examine the means, the coefficient is 50 percent greater for trades below the quoted size (.032 versus .021). If we examine the medians, the difference in magnitudes is again quite different (.025 opposed to .007). Although the slope coefficients are larger, so are the standard errors. The slope coefficients for trades above the quoted size are even less statistically significant in this sample.

B: Correctly Ordering Trades and Quotes.

The quote and trade data we use were entered into the exchange reporting system separately. Thus a trade that follows a quote in our data set may have preceded the quote on the exchange floor. Lee and Ready (1991) find that over half of the trades that are close in time to quote changes occur after the specific quote change. This temporal correlation may imply that the trade prompted the quote change, but the events were recorded in the wrong order. It is also consistent with the events happening close in time but not being casually related. We can use our data to directly test for a statistical relation between the quote change and the trades which are recorded after the quote change. We included as an additional explanatory variable any trade that followed a quote revision by less than 10 seconds. These are the trades that may have actually preceded the quote revision. If these trades were out of sequence, they should be classified as a buy or a sell based on the prior quotes. This is the way we classify the trade. When this variable is included in our regression, along with the other variables, it adds little to the explanatory power of the regression. The average R^2 increases from .246 to .248. The coefficient estimate is small and even the wrong sign (-.001 percent). More importantly the coefficient is very imprecisely estimated. The median value of the t-statistic is -0.18. Although the miss ordering of trades and quotes probably occurs in our data, it does not play a significant role in our results.

C: Asymmetric Quote Revisions: Are Separate Bid and Ask Revisions Relevant?

Until now we have been examining changes in the midpoint of the quotes. We know from Figure 1 that the bid and ask are not always revised together. By itself, however, this is uninformative. Since prices are discrete, situations will arise where one quote is changed and the other is not. The purpose of examining bid and ask changes separately is to test the robustness of our results to the presence of limit orders. Limit orders placed inside the specialist's quotes will alter spread midpoints. If these limit orders arrive at random, i.e. they do not predictably follow purchases or sales, then the presence of limit orders will not alter our coefficient estimates.

When the posted quotes represent public limit orders and not the specialist's quotes, mechanical quote revisions may arise. When a market buy order hits and completely fills a limit sell order, the quote on the ask side will revert to the higher ask price of the specialist. Buys will thus be followed by upward revisions in the midpoint of the quotes we observe, but not necessarily in those of the specialist. We will therefore observe one-sided quote revisions. By estimating our model separately for bid and ask changes, we can quantify the empirical significance of such mechanical quote revisions.

When separate regressions are run for bid and ask revisions, a clear asymmetry emerges.[7] Trades at the ask have a greater impact on the ask than on the bid. The results for trades at the bid are similar (see Table V). The asymmetry we find implies that the mechanical quote revisions we discussed above do occur. However, even though the magnitudes of the coefficients change -- they are larger for trades on the same side of the spread and smaller for trades on the opposite side of the spread -- the functional form of the relation is the same. Trades that exceed the quoted size are followed by larger quote revisions. These quote revisions, however, are still almost independent of the size of the trade. Even when examining the revision in the bid price following trades at the ask, we see this same relation.

D: Trades Inside the Quotes

So far we have excluded trades inside the spread. When a trade occurs at the ask it is clear that the buyer is the more impatient trader. The specialist or limit order has been waiting to sell. When trades occur inside the spread, identifying the more impatient trader is difficult. Misclassifying buys and sells is more likely for these trades. The coefficients are thus more likely to be biased toward zero. To test the effect on our results of omitting trades inside the spread we included these trades as a separate variable. We found that the estimated coefficient was small and statistically insignificant. The mean t-statistic was 0.11. Given that the coefficient on the inside trades is close to zero, it is not surprising that none of the other coefficients was altered by this addition.

V: Concluding Remarks

This paper examines the relation between trades and quote changes for 119 stocks. As the adverse selection literature would suggest, trades do induce quote revisions. There is evidence of substantial market liquidity, however, as quote revisions induced by trades are quite small. This is expected given that our sample is all large firms.

We find a very significant role for the quoted size which is posted with the bid and the ask price. The role of the quoted size has been ignored in prior work and we find this omission explains the concavity found in prior work. We estimate separate quote revisions rules for trades larger and smaller than the quoted size. Once this is done, the relation between trades and quote revisions is no longer concave. The form of the quote revision changes dramatically once the trade size exceeds the quoted size. Market impact is much higher once the quoted size has been exceeded. For midsized trades, the quote revision is seventy percent larger for trades beyond the quoted size. Not only do we find the total quote revision to be larger for these trades, we also find that it is largely independent of the size of the trade. Although increasing the trade size beyond the quoted size has a large effect on the quotes, further increases in the trade size have none.

These results are inconsistent with the specialist and traders placing limit orders using the quoted size to sort traders into informed and uninformed groups. The specialist does not have to take larger trades. Thus if he voluntarily accepts the other side of these trades, we would expect them made by individuals perceived to be less informed. Given the larger quote revision following these trades, this can not be the case. Instead these results are consistent with the specialist and public limit orders providing liquidity, but only for small trades. Once the size of the trade exceeds his limits, liquidity declines appreciably. The decline is equally large for trades that exceed the quoted size by a little or by a lot.

Finally our results point out that not all trades move the quotes. In fact, only a fraction of the trades statistically can be shown to induce quote changes. Our finding is not a result of the limitation that prices be quoted in eighths of a dollar. Even after accounting for this factor, we find that quotes induce either an immediate quote revision or none at all. If only a limited number of trades are responsible for most of the movements in prices, then identifying the characteristics of these trades is a useful avenue for further research.

Appendix: Potential Sources of Coefficient Bias.

This appendix examines potential bias in coefficients attributable to trade misclassification and lack of specialist participation in some trades. Recall that our trade classification rule will introduce measurement error in our regressions to the extent that specialists cross their spreads when executing transactions. Figure A-1 illustrates how trade misclassification is likely to bias our coefficients. Ask trades properly classified as purchases will on average be followed by upward revisions in the quotes (solid line). Misclassified ask trades, however, will induce downward revisions in the quotes (dashed line). Estimated quote revision parameters will average the parameters implied by the upper and lower lines of Figure A-1. The center line depicts the expected outcome of estimation procedures given a ten percent misclassification rate (i.e. ten percent of the trades which we classify as floor trader purchases are actually sales).[8] Based on the results in Figure 1, this seems like an extremely high rate of misclassification.

The second problem discussed in section III is that the specialist does not participate in all trades. When the specialist does not participate as an agent his inventory does not change. Quote revisions following such trades will thus incorporate the new information implied by the trade, but will not arise due to inventory concerns. The upper line in Figure A-2 depicts the relation between quote revisions and volume for trades in which the specialist participates, i.e., trades that induce adverse selection and inventory related revisions. The lower line depicts the relation for trades in which the specialist does not participate. For these trades only the adverse selection component of the quote revisions is present. Since we cannot empirically distinguish between the two types of trades, our regression model will average the effects of the two types of trades. The averaging effect is depicted by the middle line in Figure A-2 under the assumption that the specialist acts as an agent in 40% of the trades.

Figure A-2 assumes the specialist is equally likely to participate in trades of all sizes. We know, however, that he is more likely to participate in small trades. This will alter the average quote revision function we are estimating. For small trades, the function will be closer to the upper line depicting the relation for agency trades. For large trades, the average revision will resemble the lower line depicting the relation for brokered trades. Thus, even if the relation between inventory changes, adverse selection, and quote revisions are linear, we will estimate a concave function between volumes and quote revisions (see Figure A-3). The estimated function will appear more concave then the true function.

The measurement problems discussed here will shrink the entire quote revision function toward zero -- both the intercept and the slope parameters. Thus neither can explain our findings of a larger intercept and a smaller slope for trades greater than the quoted size.

ENDNOTES

1. Take an example where the specialist is willing to purchase 2,000 shares at the bid. A floor trader has also placed a limit order to buy 4,000 shares at the bid. However, the floor trader has asked that his order not be displayed in the quoted size. The quoted size is 2,000 shares, but the available demand at the bid is 6,000 shares.

2. See Hasbrouck (1988) for a discussion of the difficulties of classifying these trades.

3. According to NYSE estimates, the specialist participates as a dealer (trading for his own account) in 45 percent of NYSE transactions while he participates as a broker (buying or selling for another trader) in 49 percent of the transactions (NYSE Fact Book, 1989).

4. Volume squared is multiplied by the sign of volume to preserve the buy/sell distinction.

5. These numbers are based on the mean estimates of the quote revision rule from Table IV. The first number uses the estimated quote revision rule for trades below the quoted size. The second number is based on the estimated quote revision rule above the quoted size.

6. Remember trades at the bid are coded with a negative trade size. Thus omitting the top five and bottom five percent of the distribution will predominantly exclude trades above the quoted size. Only 24 percent of trades exceed the quoted volumes. Estimates based on this sample have very large standard errors and no meaningful conclusions can be drawn from the results. Instead, we divided trades into those that exceed the quoted size and those that do not. We then calculated the upper and lower five percentiles for each sample separately. Observations in the upper and lower tails were then omitted from the sample.

7. Since the quadratic coefficients are close to zero and not significant, we omitted them. When they are included the results are qualitatively and quantitatively the same.

8. We also obtained these results from a simulation. The results are available from the authors.

REFERENCES

Amihud, Yakov and Haim Mendelson, 1980, Dealership market, *Journal of Financial Economics* 8, 31-53.

Blume E. Marshall, and Michael A. Goldstein, 1992, Differences in execution prices among the NYSE, the regionals and the NASD, White Center for Financial Research, working paper # 4-92.

Chan, Louis K.C. and Josef Lakonishok, 1991, Institutional trades and intra-day stock price behavior, University of Illinois Faculty Working Paper #91-0167.

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

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

Glosten, Lawrence, 1989, Insider trading, liquidity, and the role of the specialist, *Journal of Business* 62, 211-235.

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

Hasbrouck, Joel, 1991, The Summary Informativeness of Stock Trades: An Econometric Analysis, *The Review of Financial Studies* 4, 571-595.

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

Holthausen, Robert W., Richard W. Leftwich and David Mayers, 1987, The effect of large block transactions on security prices, *Journal of Financial Economics* 19, 237-267.

Lee, Charles and Mark Ready, 1991, Inferring trade direction from intraday data, *Journal of Finance* 46, 733-746.

Kyle, Albert S., 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315-1335.

Kraus and Stoll, 1972, Price impacts of block trading on the New York Stock Exchange, *Journal of Finance* 27, 569-588.

Madhavan, Ananth and Seymour Smidt, 1991, A bayesian model of intraday specialist pricing, *Journal of Financial Economics* 30, 99-134.

McInish, Thomas H. and Robert A. Wood, 1992, Hidden Limit Orders on the NYSE, mimeo.

Table I: Quote Revision Rule Estimates for Brunswick Corporation

	Estimate	Standard Error	T-Statistic
Volume Quoted Limit			
Sign(Volume)	.660	.090	7.321
Volume	.617	.109	5.663
$Volume^2$ * Sign(Volume)	-.027	.011	-2.468
Volume > Quoted Limit			
Sign(Volume)	3.117	.201	15.496
Volume	.182	.055	3.302
$Volume^2$ * Sign(Volume)	-.001	.001	-1.793
Cumulative Lagged Volume	.043	.014	3.084
Elapsed Time x Sign(Volume)	-.021	.004	-5.948
Quoted Size	.598	.040	15.136
Constant	-.092	.053	-1.731
R-Squared = 0.213 No. Observations = 6321			

The dependent variable is changes in the midpoint of the spread and is denominated in cents. Volume is denominated in 1,000s of shares and is coded as positive for buyer initiated trades (trades at the ask) and negative for seller initiated trades (trades at the bid). Separate functions are estimated for cases when the trade size (volume) is less than or equal to the quoted size and for cases when volume is greater than the quoted size. Cumulative lagged volume is the sum of signed trade sizes since the last quote change. Elapsed time is the time since the last trade. quoted size is the change in the quoted size at the bid and the ask. T-statistics are heteroscedastic consistent. The average trade size for Brunswick Corporation is 1,200 shares. The average stock price is $23.55 and the average spread is 22 cents.

Table II: Frequency Distributions of Volume Coefficients

	Volume	Quoted Limit		Volume > Quoted Limit		
	Sign(Vol)	Volume	Volume^2	Sign(Vol)	Volume	Volume^2
MEAN	.047	.019	-.001	.132	.003	.000
MEDIAN	.039	.013	-.001	.116	.002	-.000
5 PERCENTILE	.011	-.003	-.011	.057	-.004	-.000
25 PERCENTILE	.023	.008	-.002	.092	.000	-.000
75 PERCENTILE	.063	.027	-.000	.144	.006	.000
95 PERCENTILE	.118	.065	.002	.281	.020	.000
T-STATISTICS						
MEAN	9.26	4.01	-2.16	17.01	1.78	-.67
MEDIAN	9.13	3.66	-1.90	15.87	1.54	-.57
5 PERCENTILE	4.01	-.58	-6.88	8.21	-1.60	-4.86
25 PERCENTILE	6.60	1.95	-3.35	13.37	.38	-2.14
75 PERCENTILE	11.68	6.00	-.68	20.71	3.45	.78
95 PERCENTILE	15.80	9.21	1.10	37.03	6.13	2.68
% Sig. at 1.0%	99%	65%	39%	100%	29%	22%

For each of the 118 firms in our sample we ran the regression reported in Table I for Brunswick Corporation. The dependent variables is the change in the midpoint of the quotes. This table contains the distribution of the trade size coefficients and the associated t-statistics. The coefficients are normalized by the average stocks price. The t-statistics are heteroscedastic consistent. Each regression also contains the cumulative lagged volume, time since the last trade multiplied by sign(volume), change in the quoted size, and a constant. The distributions of these coefficients are reported in Table III. Number of stock issues = 119.

Table III: Frequency Distributions of the Other Coefficients

	Cumulative Lagged Volume	Sign(Volume) x Elapsed Time	Quoted Size
MEAN	.000	-.001	.004
MEDIAN	.000	-.001	.004
5 PERCENTILE	-.005	-.002	-.005
25 PERCENTILE	-.000	-.001	-.001
75 PERCENTILE	.001	-.000	.007
95 PERCENTILE	.004	-.000	.019
T-STATISTICS			
MEAN	1.29	-5.82	6.29
MEDIAN	1.22	-5.75	6.40
5 PERCENTILE	-2.14	-9.52	-2.55
25 PERCENTILE	.22	-7.02	-.57
75 PERCENTILE	2.57	-4.48	11.72
95 PERCENTILE	4.87	-2.85	18.98
% Sig. at 1.0%	28	97	63

For each of the 118 firms in our sample we ran a regression. The dependent variable is the change in the midpoint of the quotes. The table reports the distribution of the coefficients not reported in Table II. Cumulative lagged volume is the sum of signed trade sizes since the last quote change. Elapsed time is the time since the last trade.   quoted size is the change in the quoted size at the bid and the ask. The coefficients are normalized by the average stocks price. T-statistics are heteroscedastic consistent. Each regression also includes two quadratic functions of volume -- one for trades less than or equal to the quoted size and one for trades greater than the quoted size. These coefficients are reported in Table II.

Table IV: Frequency Distributions of Volume Slope and Intercept Coefficients
Middle 90% of the Volume Distribution

	Volume ≤ Quoted Limit			Volume > Quoted Limit		
	Sign(Vol)	Volume	Volume^2	Sign(Vol)	Volume	Volume^2
MEAN	.038	.032	.033	.116	.021	-.003
MEDIAN	.027	.025	-.008	.096	.007	-.001
5 PERCENTILE	.006	-.156	-.358	.038	-.030	-.020
25 PERCENTILE	.017	.013	-.039	.068	-.000	-.005
75 PERCENTILE	.047	.094	.000	.138	.037	.000
95 PERCENTILE	.121	.296	.288	.280	.151	.026
T-STATISTICS						
MEAN	4.53	1.73	-.81	8.50	1.48	-.98
MEDIAN	4.26	1.74	-.85	8.40	1.24	-.73
5 PERCENTILE	1.21	-1.03	-2.69	2.93	-1.81	-4.02
25 PERCENTILE	2.64	.71	-1.72	6.06	-.07	-2.14
75 PERCENTILE	6.11	2.77	.08	10.55	2.80	.13
95 PERCENTILE	8.81	4.46	1.51	14.79	6.67	1.68
% Sig. at 1.0%	76%	30%	12%	97%	32%	24%

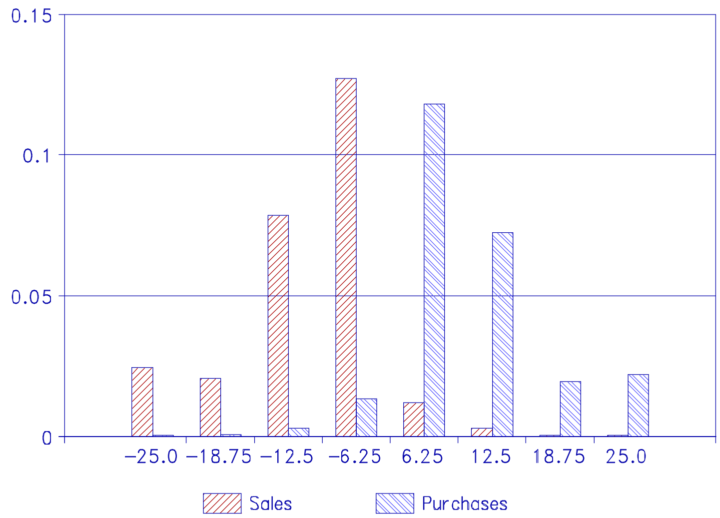
These estimates are based on a subsample of the data used in Table II. This subsample omits the observations with extreme trade sizes. We calculated the frequency distribution of trade sizes (volume) for trades above and below the quoted size separately. For each distribution, we omitted the top and bottom five percent of the distribution. Since trades at the bid are coded as negative volume, this excludes the largest trades. The coefficients are normalized by the average stocks price. T-statistics are heteroscedastic consistent. Each regression also contains the cumulative lagged volume, time since the last trade times sign(volume), change in the quoted size, and a constant.

Table V: Frequency Distributions of Volume Coefficients
Estimating Bid and Ask Changes Separately

Coefficient	MEAN	25 %	MEDIAN	75 %
A: Dependent Variable: Revision in the Ask Price				
Volume Quoted Limit				
Ask Side Trades				
Sign(Volume)	.088	.055	.077	.105
Volume	.016	.005	.010	.022
Bid Side Trades				
Sign(Volume)	.013	-.009	.014	.042
Volume	.006	.001	.005	.011
Volume > Quoted Limit				
Ask Side Trade				
Sign(Volume)	.209	.134	.176	.228
Volume	.003	.000	.001	.005
Bid Side Trade				
Sign(Volume)	.063	.030	.059	.081
Volume	.003	.000	.001	.003
B: Dependent Variable: Revision in the Bid Price				
Volume Quoted Limit				
Ask Side Trade				
Sign(Volume)	.013	-.010	.013	.036
Volume	.002	.001	.004	.007
Bid Side Trade				
Sign(Volume)	.089	.056	.079	.108
Volume	.016	.006	.010	.021
Volume > Quoted Limit				
Ask Side Trade				
Sign(Volume)	.063	.036	.059	.085
Volume	.003	.000	.001	.004
Bid Side Trade				
Sign(Volume)	.201	.131	.166	.223
Volume	.003	.000	.001	.004

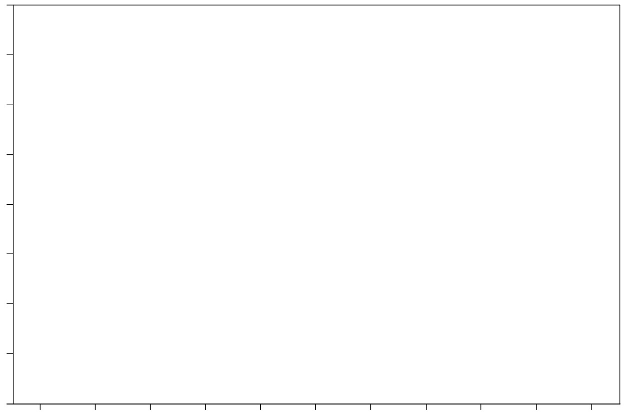
For each of the 118 firms in our sample we ran two regressions. One used the change in the ask as the dependent variable, the other used the change in the bid as the dependent variable. The distribution of coefficients are reported in panel A (change in the ask) and panel B (change in the bid). The coefficients are normalized by the stock's average price. T-statistics are heteroscedastic consistent. In addition to the volume variables, each regression also contains the cumulative lagged volume, elapsed time since the last trade times sign(volume), change in the quoted size, and a constant.

Figure 1: Frequency Distribution of Quote Revisions



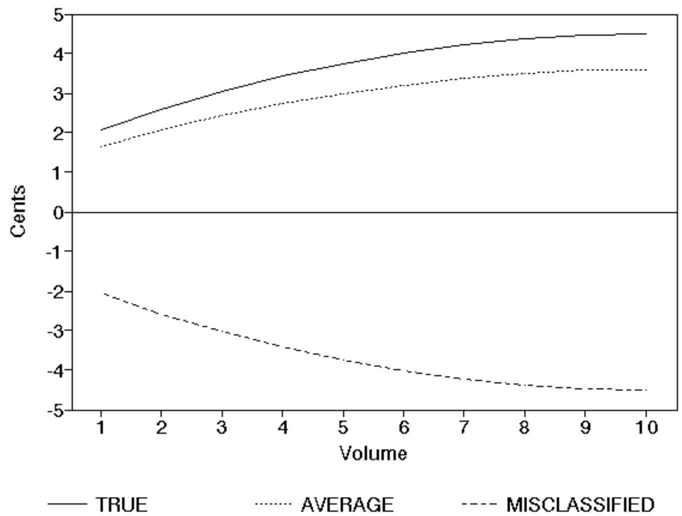
Quote revisions are expressed in cents. We classify trades at the ask as buyer initiated trades and trades at the bid as seller initiated trades. Quote changes of zero are not graphed. They comprise 69 percent of the seller initiated sample and 71 percent of the buyer initiated sample. This figure is based on 200,554 purchase transactions and 199,784 sale transactions. The far left bin includes all quotes changes less than or equal to -25 cents. The far right bin includes all quotes changes greater than or equal to 25 cents. Quote revisions of 6.25 cents occur when only the bid or only the ask are revised.

Figure 2: Quote Revision Rule



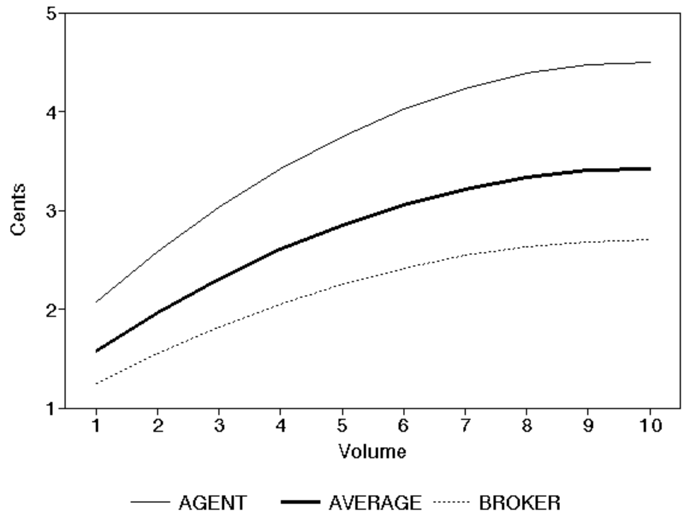
These functions are based on the median coefficient estimates from Table II. Separate functions are graphed for trades below the quoted size (bottom line) and above the quoted size (top line). The average trade less than the quoted size is for 860 shares; the average trade greater than the quoted size is for 5200 shares. The average quoted size is 4,000 shares at the bid and the ask.

Figure A-1: The Effects of Trade Misclassification on Coefficients



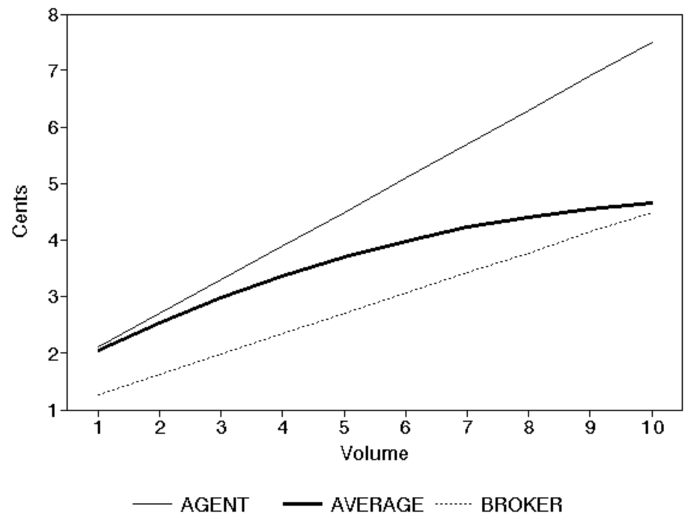
This figure graphs the relation between the trade size and the quote revision. The top line depicts the relation between quote revisions and volumes correctly classified as floor trader purchases. The bottom line depicts expected revisions as a function of trade size for purchases incorrectly classified as sales. The center line depicts the average relation we will estimate under the assumption that we misclassify ten percent of our trades.

Figure A-2: The Effects of Specialist Non-Participation on Parameter Estimates



The figure graphs the relation between the trade size and the quote revision under alternative assumptions about specialist participation. The top line depicts the relation when the specialist participates directly as a dealer; while the bottom line depicts the relation when he acts only as a broker. When the specialist acts as a broker quote revisions will arise only due to adverse selection. When he acts as a dealer quote revisions will arise due to both inventory and adverse selection. Because we cannot distinguish those trades in which the specialist participates, the function we estimate will lie between the broker and dealer lines. The average function we depict assumes that the specialist participates as a dealer in 40% of exchange trades.

Figure A-3: Concavity Due to Non-participation by the Specialist



The figure graphs a linear relation between the trade size and the quote revision under the assumption that the specialist acts as both a dealer and a broker. If the specialist is more likely to participate in smaller trades then the relation we estimate will be concave. In this example we have assumed that the specialist participation as a dealer varies from 95% for small trades to 5% for large trades.