Sun Yat-Sen Management Review
P73-104

The Quoting Behavior of a Specialist on the NYSE

Min-Hsien Chiang
Institute of International Business
National Cheng Kung University
Tainan, TAIWAN

Abstract

This paper investigates the quote decision of the specialist on the NYSE. It is believed that the quote decision will affect many aspects on the trading strategies of different types of market participants, such as informed traders, liquidity traders, and market makers themselves, and on security price characteristics, such as volatility, the price evolution path, the spread size, and the spread pattern. Although the bid-ask spread behavior has been broadly explored in theories and empirical studies within the market microstructure area, there are few research works concentrating on the investigation of fundamental elements of a quote, i.e., the bid-ask prices and associated sizes. Therefore, the theoretical models and empirical estimation show how a specialist decides his bid-ask prices and sizes in this paper.

Key Words：Bid-Ask Spread, Bid-Ask Size, Specialist, Market Microstructure

I. Introduction

The fundamental economic model trying to find the equilibrium prices in the exchange markets focuses on the Walrasian sequential batch auction market in which the auctioneer, not a market participant, standing ready in the trading process and having full knowledge of all traders' demand and supply schedules, can determine an equilibrium price clearing the market transactions. This kind of call market can be applied to only those markets with a periodic clearing procedure. In real world, the financial markets, however, do not have this kind of elementary and ideal trading mechanism. Most of them use a continuous dealer or auction mechanism, which is very different from the frictionless Walrasian auction mechanism. On the NYSE and other similar markets, such as AMEX, a single market maker, called specialist, responsible for the stocks he is registered in, stands ready to match the incoming orders from the trading crowd or trades against these orders on his own account. Following the regulations of the NYSE, specialists should maintain a fair and orderly market and, therefore, have to provide enough liquidity services to the market in order to minimize the disparity between supply and demand. In order to fulfill this responsibility and trade on their own benefits, specialists should post quotes1 to make the trading smooth and at least not to get large losses in the transactions. When performing those tasks, specialists will bear some ordering and transaction costs and undertake transaction risks that must be compensated for. Consequently, a rational specialist will consider these factors when he posts his quotes and participates in transactions.

As for decisions of the spreads, there are two major theories, inventory control theory and information asymmetry theory, explaining how a market maker comes to his quote decision. The inventory control model explains the formation of the spread as the market makers bear the risk of undesired inventories while the information asymmetry model expounds the spread as the market makers' losses to the informed traders. Those losses will be compensated by the gains from trading against uninformed traders. Stoll (1989) provides an explanation of the difference about these two theories. He explains that the inventory control model predicts both bid and ask prices will move, but the true stock price will still be unchanged, since market makers adjust their holdings of stocks using bid and ask prices

---

[1] Effective quotes should comprise of bid price, bid size, ask price, and ask size on the NYSE.

without any other information flowing into the market. The information asymmetry model predicts that both bid and ask prices move and the true stock price is changed as well due to the additional information flowing into the market. These explanations about these two theories are based on the symmetric movement assumption of the bid and ask prices around the true prices. However, Jang and Venkatesh (1991) provide evidence that "both changes" happens less than 25% of their NYSE and AMEX data, while there are more than 75% of observed quote revisions falling into the one-sided revision category (i.e., either bid or ask moves) following one stock transaction which is inconsistent with the predictions of the information asymmetry hypothesis and inventory control hypothesis provided by Stoll (1989) and others. They conclude that the quote revisions are driven a lot by those factors unrelated to the inventory control hypothesis and information asymmetry hypothesis.

In addition to quote decisions, the specialist faces size (i.e., quoted volume) decision when dealing securities. According to the SEC regulations, in addition to posting the quoted prices, market makers have to be firm about quoted sizes of both sides. Consequently, a complete quote for a specialist should include not only the bid price and the ask price, but also the bid size and the ask size.

Intuitively, specialists will reduce the market liquidity when they believe the probability of trading against informed traders increases. In this case, a specialist can control liquidity by adjusting not only quoted prices, but also quoted sizes to control the liquidity services. Accordingly, models or empirical studies considering both price and size decisions will improve our understanding of the quote decisions of market makers. Lee, Mucklow, and Ready (1993) point out that most earlier studies[2] of the informational asymmetry models focus on only one dimension of market liquidity, i.e., quoted prices, and assume the size[3] to be the same on each side of the quote, e.g., one unit. However, ignorance of the size decision probably leads us to misunderstand the true quote decisions of the market makers. Therefore, Lee, Mucklow, and Ready (1993) provide evidence showing that the intraday pattern of the total quoted sizes, i.e., the sum of the bid size and the ask size, is U-shaped like the intraday spread pattern and that the market liquidity will increase when the quoted sizes increase. Also, they found that a specialist tends to decrease

[2] For example, Copeland and Galai (1983), Glosten and Milgrom (1985), and Easley and O'Hara (1992).

[3] Lee, Mucklow and Ready use quoted depth instead of quoted size here. Both terms represent the same meaning.

the quoted sizes and increase the spread before the earning announcement, an informational event. These findings indicate that a specialist tends to quote higher spreads and lower sizes when the possibility of informed trades increases. This shows that a specialist will set the quoted prices and the corresponding quoted sizes to control market liquidity. Charoenwong (1995) derives a model showing that the quoted size decreases (for either side of the quote) when the probability of informed trades goes up.

In this paper, unlike Jang and Venkatesh (1991), we argue that the bid and ask prices will not be changed symmetrically around the true prices even though the adverse selection problem and inventory cost problem exist. This is because specialists determine the bid and ask prices using asymmetric viewpoints. Meanwhile, the predictions of movement of bid or ask prices due to considerations of adverse selection and inventory costs is not what Stoll (1989) states. Instead, a specialist in the stock market will post his bid and ask prices by adding different weights to either side. That is, a specialist tends to move his ask (bid) price if the information in the market concentrates on the buy (sell) side and indicates that the ask (bid) price is in the wrong price level or if the market maker has larger (less) stock holdings and try to adjust his stock holdings to his desired inventory level.[4] Meanwhile, we consider two dimensions of the quote, i.e., the quoted prices and quoted sizes as well. Unlike Lee, Mucklow and Ready (1993), and Charoenwong (1995), we investigate the simultaneous quote decisions regarding these two dimensions on each side of the quote and find that they are affected by information asymmetry factors. We develop a theoretical model showing that informed trading affects decisions about prices and sizes on each side of the quote.

II. Theoretical Model of Decision Making of the Complete Quote

2.1 The Bid Side Decision

In this section, we want to propose a theoretical model to explain how a

[4] Refer to Madhavan and Smidt(1993) for more about how the desired inventory affects the decision of a specialist.

risk-neutral specialist optimally posts his quotes and the related number of shares he is willing to trade. Previous studies have intensively focused on the size of the bid-ask spread, but the bid-ask spread is only one dimension of market liquidity, as pointed out by Harris (1990) and Lee, Mucklow, and Ready (1993). Therefore, a model considering both dimensions, quoted prices and quoted sizes, may give us a more complete picture about the quote behavior of a specialist, compared to previous models concerning only the price dimension. The following model is designed to clarify how a specialist determines his quote behavior and is modified from the model of Charoenwong (1995). Following the argument of Bagehot (1971), it is assumed that a specialist can not gain from trading against informed traders, but will be reimbursed from trading against liquidity traders or against uninformed traders who participate for exogenous reasons, even though they do not have superior information about the market.[5]

Without loss of generality, we consider the bid side decision first. Alternatively, the ask side decision can be derived in the same fashion. Consider that a specialist would have a perceived value, b, based on the information set after the last trade. The specialist would set up a bid price formed by three components, the perceived value b, the profit margin (or order processing cost) φ, and the risk premium z. Then, the bid price would be $b-\varphi-z$. Although a specialist has a perceived value and a profit margin in mind, he also considers that informed traders may have private information beyond his information set. According to this "hazard", a specialist would add an additional term, risk premium z, to reduce this loss. On the other hand, the market maker would have to make a size commitment, Q_b, to complete the bid side quote. It is also assumed that the trading volume would not exceed this commitment for all the traders, i.e., informed traders and the uninformed traders. The informed traders trade the maximum quantity, Q_b, while the uninformed traders trade $x(z)$. The first derivative of $x(z)$ with respect to z, x_z, would be negative because the lower the bid price, the less the uninformed traders want to trade. Furthermore, if a specialist reduces the bid price too much, the floor traders can post a better bid price to get trades. According to this trade competition, we set up a loss function, $L(z)$, whose first

[5] This setting is employed by Kyle (1985), Glosten and Milgrom (1985), Easley and O'Hara (1987), Admati and Pfleiderer (1988), and Foster and Viswanathan (1990).

derivative with respect to z, L_z, would be positive. Suppose that the informed traders have private information about the security they trade, and the informed traders have the liquidation value of the security, $\tilde{b}$. Moreover, we assume $\tilde{b}$ is no more than $b-\varphi-z$, the bid price of a specialist, since informed traders would like to trade only when there are profits implied in the security information.

From the assumptions above, we can formulate the following objective function for a specialist:

$$\underset{z,Q_b}{Max}\,\pi = (1-P_I)(\varphi+z)Min(Q_b, x(z)) - P_I Q_b (b-\varphi-z-\tilde{b}) - L(z) \qquad (1)$$

where π represents the economic profit of the specialist, and P_I represents the probability that a specialist trades against informed traders. In equation (1), the first term, $(1-P_I)(\varphi+z)Min(Q_b, x(z))$, is the gain from trading against the uninformed traders, while the second term, $P_I Q_b(b-\varphi-z-\tilde{b})$, is the loss to the trade against the informed traders.

The equation (1) can be rewritten as follows

$$\underset{z,Q_b}{Max}\,\pi = (1-P_I)(\varphi+z)[Q_b - Max(Q_b - x(z),0)] - P_I Q_b(b-\varphi-z-\tilde{b}) - L(z) \qquad (2)$$

Let $G(Q_b,z) = Max(Q_b - x(z),0)$. Therefore, the first order conditions for equation (2) would be

$$\frac{\partial\pi}{\partial z} = (1-P_I)(Q_b - G) - (1-P_I)(\varphi+z)G_z + P_I Q_b - L_z = 0 \qquad (3)$$

$$\frac{\partial\pi}{\partial Q_b} = (1-P_I)(\varphi+z)(1-G_{Q_b}) - P_I(b-\varphi-z-\tilde{b}) = 0 \qquad (4)$$

using equations (3) and (4), we can derive the following solutions:

$$z = \frac{P_I(b - \varphi - \tilde{b}) - (1 - P_I)(1 - G_{Q_b})\varphi}{1 - G_{Q_b} + P_I G_{Q_b}} \tag{5}$$

$$Q_b = (1 - P_I)G + (1 - P_I)(\varphi + z)G_z + L_z \tag{6}$$

Given the two solutions above and the assumption, $x(z) < (\varphi + z)(-x_z)$,[6] we can consider two solutions under the two situations of G:

(1) $Q_b \geq x(z)$

In this situation, $G_{Q_b} = 1$ and $G_z = -x_z$. Inserting these two solutions into equations (5) and (6), we obtain the risk premium z and the bid size Q_b as follows

$$z = \frac{P_I(b - \varphi - \tilde{b})}{P_I} = b - \varphi - \tilde{b} \tag{7}$$

$$Q_b = \frac{L_z - (1 - P_I)((\varphi + z)x_z + x(z))}{P_I} \tag{8}$$

Proposition 1: *If the quoted bid size is larger than the quantity of uninformed trades, then the specialists decrease their bid sizes when the probability of trading against the informed traders increases.*

Proof of proposition 1

Taking a first partial differential of Q_b with respect to P_I, we obtain

$$\frac{\partial Q_b}{\partial P_I} = -\frac{L_z - (1 - P_I)((\varphi + z)x_z + x(z))}{P_I^2} + \frac{(\varphi + z)x_z + x(z)}{P_I} \tag{9}$$

Since $x(z) < (\varphi + z)(-x_z)$, $L_z > 0$, it follows that $\partial Q_b / \partial P_I < 0$. Q.E.D.

---

6 This condition guarantees that the optimal quoted size is larger than 0. It will not, however, cause any serious problem against the rational intuition. Note that $(\varphi + z)(-x_z)$ is the marginal loss for the specialists once they increase one unit of the risk premium, z. Therefore, the condition $x(z) < (\varphi + z)(-x_z) \Rightarrow 1 < \frac{(\varphi + z)(-x_z)}{x(z)}$ means that the quoted size decision of the specialist always changes until the marginal loss of the increasing risk premium is larger than the aggregate quantity of the noise traders.

From equations (7) and (8), we see that the optimal risk premium, z, should be $b-\varphi-\tilde{b}$, which causes no loss to the informed traders if the quoted size on the bid side exceeds the quantity of uninformed trades. However, if the probability of trading against the informed traders increases, the specialist would try to decrease his quoted size.

(2) $Q_b < x(z)$

In this situation, $G_z = G_{Q_b} = 0$. Then

$$z = P_I(b-\tilde{b})-\varphi \tag{10}$$

$$Q_b = L_z \tag{11}$$

Proposition 2: *If the quoted bid size is smaller than the trade quantity of the uninformed traders, when the probability of trading against the informed traders increases, the specialists would decrease their bid prices.*

Proof of Proposition 2

We take a first derivative of equation (10) with respect to P_I and we obtain

$$\frac{\partial z}{\partial P_I} = b-\tilde{b}-\varphi \tag{12}$$

Since $\tilde{b} \le b-\varphi-z$, it is obvious that $\partial z/\partial P_I$ > 0. Q.E.D.

From the equation (12), we know that the optimal risk premium, z, increases once the probability of trading against the informed traders increases.

Meanwhile, from equations (7), (8), (10), and (11), we know that the specialist decreases the bid price and size once the risk premium, z, is not specified as its optimal value and when the probability of trading against the informed traders increases.

2.2 The Ask Side Decision

In the same fashion and with similar assumptions about the bid side decision, we can build up the objective function for the ask side decision. In this section, we assume that the ask price of a specialist would be $a+\varphi+z$, where a is the perceived ask price of a specialist, and the quoted ask size is Q_a. Meanwhile, informed traders have the liquidation value of the security, $\tilde{a}$, which is not less than the ask price of a specialist. Therefore, the objective function for the specialist is as follows:

$$\underset{z,Q_a}{Max}\,\pi=(1-P_I)(\varphi+z)Min(Q_a,x(z))-P_IQ_a(\tilde{a}-a-\varphi-z)-L(z) \tag{13}$$

The first order conditions for equation (13) would be

$$\frac{\partial\pi}{\partial z}=(1-P_I)(Q_a-G)-(1-P_I)(\varphi+z)G_z+P_IQ_a-L_z=0 \tag{14}$$

$$\frac{\partial\pi}{\partial Q_a}=(1-P_I)(\varphi+z)(1-G_{Q_a})-P_I(\tilde{a}-a-\varphi-z)=0 \tag{15}$$

where $G=Max(Q_a-x(z),0)$. Solving the equations (14) and (15) for z and Q_a, we obtain the following results:

$$z=\frac{P_I(\tilde{a}-a-\varphi)-(1-P_I)(1-G_{Q_a})\varphi}{1-G_{Q_a}+P_IG_{Q_a}} \tag{16}$$

$$Q_a=(1-P_I)G+(1-P_I)(\varphi+z)G_z+L_z \tag{17}$$

Then, we derive the solutions for z and Q_a under two conditions.

(1) $Q_a\geq x(z)$

Under this condition, $G_{Q_a}=1$ and $G_z=-x_z$. Substituting these two terms into equations (16) and (17), we can get the following

$$z=\frac{P_I(\tilde{a}-a-\varphi)}{P_I}=\tilde{a}-a-\varphi \tag{18}$$

$$Q_a=\frac{L_z-(1-P_I)\left((\varphi+z)x_z+x(z)\right)}{P_I} \tag{19}$$

Proposition 3 *If the quoted ask size is larger than the quantity of uninformed trades, when the probability of trading against* *the informed traders increases, the specialists will decrease their ask size.*

Proof of proposition 3

Taking a first partial differential of Q_a with respect to P_I, we obtain

$$\frac{\partial Q_a}{\partial P_I} = -\frac{L_z - (1 - P_I)((\varphi + z)x_z + x(z))}{P_I^2} + \frac{(\varphi + z)x_z + x(z)}{P_I} \qquad (20)$$

Since $x(z) < (\varphi + z)(-x_z)$, $L_z > 0$, it follows that $\partial Q_a / \partial P_I < 0$. Q.E.D.

From equations (18) and (19), as in the bid side decision, we see that the optimal risk premium, z, should be $\tilde{a} - a - \varphi$, which will cause the loss to the informed to be zero if the quoted size in the ask side is larger than the trading quantity of the uninformed traders. However, if the probability of trading against the informed traders increases, the specialist would try to decrease his quoted size.

(2) $Q_a < x(z)$

Under this situation, $G_z = G_{Q_a} = 0$. Given this, we can derive the following solutions:

$$z = P_I\,(\tilde{a} - a) - \varphi \qquad (21)$$

$$Q_a = L_z \qquad (22)$$

Proposition 4: *If the quoted ask size is smaller than the trade quantity of the uninformed traders, when the probability of trading against informed traders increases, the specialists will increase their ask prices.*

Proof of Proposition 4

Taking a first derivative of equation (21) with respect to P_I we obtain

$$\frac{\partial z}{\partial P_I} = \tilde{a} - a - \varphi \tag{23}$$

Since $\tilde{a} \geq a + \varphi + z$, it is obvious that $\partial z / \partial P_I > 0$. Q.E.D.

Therefore, if the quoted ask size is less than the trading quantity of the uninformed traders, the optimal risk premium, z, would be affected by the probability of trading against the informed traders. In addition, as we see in the bid side decision, the specialist, once he can not exactly specify the optimal risk premium, z, which involves the knowledge of $\tilde{a}$ and when the probability of trading against the informed traders increases, the specialist changes both the ask price and the ask size.

From the previous models about the quote decisions of the specialist, we find that specialists react to informed traders by decreasing the liquidity of the market, i.e., increase the ask price (decrease the bid price) and decrease the ask (bid) size, when information reveals a higher possibility that informed traders have participated in the trades.

III. Empirical Examination

3.1 Empirical Examination of the Quote Price Decision

Data Description

The data used in this paper are obtained from the NYSE TORQ[7] (Trades, Orders, Reports, and Quotes) database that contains four major datasets, consolidated transactions, consolidated quotes, system orders, and a consolidated audit trail file, and covers 144 NYSE firms from November, 1990 through January, 1991. Although the database includes the trades and quotes from the NYSE and the

---

[7] For more details about TORQ database, please refer to Hasbrouck (1992), Using the TORQ Database, Finance Department, New York University.

regional markets, the majority of data come from the NYSE.[8] In the meantime, as indicated by Hasbrouck (1995), the opening trade is almost invariably located on the NYSE, and there is an "autoquote" procedure[9] maneuvered in the regional market, which causes the quotes in the regional market to be very close to the best system quotes mostly on the NYSE but widened by a small amount. Therefore, in this paper, we focus on the data of the NYSE.

We have retrieved the quoted bid and ask prices from the consolidated quote file and transaction data from the consolidated transaction file. Meanwhile, we define the quote revision as changes of any one of the quote components, i.e., bid price or ask price. This revision is different from the previous quote components. The sample of stocks for this study is constructed in the following manner. We have removed those stocks with average stock quotes less than one dollar,[10] and stocks with the total number of trades or total number of quotes at the database less than 160[11] or with more than two non-trading days. Consequently, we have 124 companies in our sample. Furthermore, in order to correct the report anomaly in the stock market indicated by Hasbrouck (1988, 1991), we rearranged the sequence of a trade and of a quote by putting the quote after the trade for those trades recorded less than 5 seconds after new quotes are posted.

Panel A of Table 1 profiles the summary statistics for those data in our sample. Since the trading and quote revision activities are very different on a trading day across firms, we report the median distribution of the sample firms for all the statistics. The mean number of quotes of a trading day is 17.161, the median is 10, and the maximum is 212, while the mean number of trades of a trading day is 51.395, the median is 19.5, and the maximum is 575. The mean trading volume of

---

[8] Hasbrouck (1995) finds that the stock information reflected on the NYSE is more than in the regional markets.

[9] We also remove some abnormal or unreasonable data from database for each company in our sample, such as out of sequence quotes, out of sequence trades, or some unreasonable quoted prices, e.g. zero quoted prices.

[10] Under the regulation of the NYSE, the minimum tick for the stock price under one dollar is 1/16, while the minimum tick for the stock price over one dollar is 1/8.

[11] 160 is an arbitrary number of trades we choose in this study and, for convenience, we construct a sufficient number of data points for later estimation. For 63 trading days in the database, the average number of trades every day is about 2.5, which are much smaller for six and half trading hours of a normal trading day.

a trading day is about 1084.7 round lots, the median is 237 round lots, and the maximum is 13884 round lots. The mean of the time between quotes is 676.56 seconds, the median is 655.5 seconds, and the maximum is 1670 seconds. The distribution shapes for the number of quotes, the number of trades, and the trading volume of a trading day are leptokurtic, which means that the higher frequencies are around the medians, while the distribution of the time between quotes is skewed to the left (0.505 < 3). Panel B of Table 1 shows that the frequency of one-sided movement of quotes occupies 78.99%, which is consistent with the findings of Jang and Venkatesh (1991) and confirms that the one-sided movement of quotes is commonly observed in the market.

Research Methodology

Our main interest is to examine how a specialist decides to change either his bid side or ask side of his quote or both sides of his quote, i.e., bid, ask or both. In general, economic theories view the selection problem of an economic agent as if he will make a specific choice if this choice can maximize his utility or is preferred to the other choices he has. Suppose a specialist has a certain utility function, U_{ij}, where the subscript i represents a certain time period i or a certain decision point i, at which a specialist makes his quote decision and the subscript j represents the choice he makes. From the bid/ask spread theories, the factors driving a specialist to change his quote will be related mainly to information asymmetry andinventory control consideration. Thus, the utility function can be expressed as $U_{ij} = f_{ij}$ (information asymmetry and inventory control variables). Consequently, a specialist will change his quotes if changes in these variables alternate his utilities toward the existent quote.

Table 1 Sample Characteristics

Panel A: The Descriptive Statistics of Medians of Variables

	Mean	Median	Maximum	Skewness	Kurtosis
Number of quotes/ a day	17.161	10	212	4.771	31.922
Number of trades/ a day	51.395	19.5	575	3.778	17.649
Trading volume/ a day (unit: round lots)	1084.7	237	13880	3.5	15.1
Time between Quotes/ a day (unit: seconds)	676.56	622.5	1670	0.505	2.536

Panel B: The frequency of the Movement for Each Category

	Ask Increase	Ask Decrease	Bid Increase	Bid Decrease	Both Increase	Both Decrease
Individual Category	28060 (19.59%)	28808 (20.11%)	29537 (20.62%)	26737 (18.67%)	11448 (7.99%)	18656 (13.02%)
Combined Category	56868 (39.70%)		56274 (39.29%)		30104 (21.01%)	

The percentage in the parenthesis represents the proportion of frequencies of the category to total frequencies in the sample

We use the multinomial logit model to examine the choice behavior of a specialist. The multinomial logit model is one of limited-dependent-regression models and is heavily used in investigating consumer choice problems in marketing and in transportation. The specification of the multinomial logit model is given by the following expression (choice 0 as the normalization or the base choice)

$$P(y_i = j) = \Phi(\beta_j' \mathbf{x}_i) = \frac{e^{\beta_j' \mathbf{x}_i}}{\sum_{k=0}^{J} e^{\beta_k' \mathbf{x}_i}} \quad j = 1, 2, \ldots\ldots, J \tag{24}$$

where $P(y_i = j)$ represents the probability of choice j at time period i, β_j represents the coefficient vector for choice j, and $\mathbf{X}_i$ represents the independent variable vector at time period i. Meanwhile, we assume that the distribution of error terms in equation (24) follows Weibull distribution for convenience. Therefore, the log likelihood function is given by the following:

$$\log L = \sum_{i=1}^{n}\sum_{j=0}^{J} y_{ij} \log P_{ij} \tag{25}$$

We can solve the maximum likelihood function (25) to obtain the coefficients of the model. After estimating equation (24), we can understand how a specialist puts weights on each factor $\mathbf{X}_i$ for each choice j and makes his own quotation decision through these influences of each variable.

In this paper, we classify the quote choices of a specialist as two models, the basic model and the detailed model. The first model, the basic model, demonstrates the quote-revision choice between the bid price and the ask price. Thus, a specialist could have the following three choices:

$y_i = 1$ if the specialist moves his ask price only (AM),
$y_i = 2$ if the specialist moves his bid price only (BM),
$y_i = 3$ if the specialist moves both the ask price and the bid price.

Under this basic model, we can understand how a specialist will choose his move to change his ask price, bid price, or both. Furthermore, since the decision of a specialist will not only involve moving the quote components but also the direction of changes (increase or decrease), we classify the choices into the following detailed model with more detailed categories:[12]

$y_i = 1$ *the specialist increases the ask price (AM_INC),*
$y_i = 2$ *the specialist decreases the ask price (AM_DEC),*
$y_i = 3$ *the specialist increases the bid price (BM_INC),*
$y_i = 4$ *the specialist decreases the bid price (BM_DEC),*
$y_i = 5$ *the specialist increases both the ask price and the bid price (Both_INC),*
$y_i = 6$ *the specialist decreases both the ask price and the bid price.*

---

[12] The situations in which the bid increases (decreases) and the ask decreases (increases) have few observations in each firm. Hence, we ignore those situations in this paper.

In the detailed model above, we can understand more about the choice decision of a specialist. We use 3 choices in the basic model and choices in the detailed model as the basic choices for estimation which will set the coefficients of the basic choices zero.

For the estimation models, we construct independent variables which can represent information asymmetry and the inventory control aspects of the trading activity observed by the specialists. Fundamentally, among the eleven variables in our independent variable set, there are five different kinds.

$\Delta t =$	Elapsing time between two different quotes.
$NT =$	Number of trades between different quotes
$IBS_{t-i} =$	Three lags (i =1,2,3) of a transaction direction indicator that takes the value 1 if the transaction price is greater than the mid-point of the prevailing quote and value -1 if the transaction price is less than the mid-point of the prevailing quote. If the transaction price is equal to the mid-point of the prevailing quote, we compare this transaction price with a different previous quote until we find no equality or no previous quotes that are comparable. This indicator will take the value 0 if we cannot decide its direction.
$DV_{t-i} =$	Three lags (i =1,2,3) of the dollar trading size defined as the (t-i)th transaction price times the number of shares traded.
$ITQ_{t-i} =$	Three lags (i =1,2,3) of a trading size indicator that takes the value 1 if the trading volume is larger than the prevailing quoted size on the side indicated by the transaction direction indicator, IBS_{t-i}, 0 otherwise.

The first variable, Δt: elapsing time between two different quotes (or the time between quotes, hereafter), is constructed following the implication of Easley and O’Hara (1992) and the empirical findings of Fletcher (1995) about the trading price convergence process. Since the trading sequence of the informed traders depends on the security prices implied by their private information, the trading behavior of the informed traders will cause time between trades to be related to the rate of the price convergence. As found by Fletcher (1995) and Hausman, Lo, and MacKinlay (1992), the time between trades is an informational indicator that can convey some information beyond those in the security prices and the trading volume, and the longer the time between trades, the higher the price volatility. In other words, the larger the time between trades, the higher probability that the adverse selection problem will happen. We follow the implication of this argument that if the time between quotes increases, there is a greater chance that the information uncertainty will happen because the time between quotes reflects the reaction of market makers to the information flows in the market.

The number of trades between different quotes, NT, reflects the informational and inventory control proxies as well. It is believed that when the trading intensity becomes larger, the informed traders will trade more at this time because they can camouflage their moves as Admati and Pfleiderer (1988) suggest that the informed traders will trade actively in periods when liquidity trading is concentrated. On the other hand, Benston and Hagerman (1974) and McInish and Wood (1992) suggest that increases in the number of trades will reduce the ordering cost, if the number of trades increases because it will provide economies of scale to market makers due to savings in inventory and other transaction costs, such as the order processing cost. Therefore, the number of trades will represent these two different concepts.

The transaction direction indicator, IBS, represents the market trading concentration that denotes the trade that is buyer-initiated (+1, at ask side), seller-initiated (-1, at bid side) or indeterminate (0). This variable could stand for an informational proxy. Easley and O'Hara (1987)[13] propose that the higher (lower) stock value signal inferred from the trading will tend to affect the ask (bid) price most. Hence, if the trade tends to be on the ask (bid) side, the information flow will have a tendency to indicate that the ask (bid) price is misquoted. Also, IBS could represent an inventory control proxy. When the transaction is buyer-initiated (seller-initiated), this could produce an inventory shortage (superfluous inventories) of the market maker and, therefore, the market maker will reverse this situation by posting a quote to induce the trading crowd to issue sell (buy) orders. With the same arguments as IBS, the dollar trading volume variable, DV (hereafter, the dollar trade size), also represents the informational and inventory control proxies as we point out above. Furthermore, in addition to reflecting informational impacts of the security prices of the block trade behavior indicated by Cheng and Madhavan (1994) and Seppi (1990, 1992), the dollar trade size also reflects dollar value gains or losses of the specialists trading against larger trades. Since the previous research emphasizes the effects of the trading volume only, the dollar trade size variable will

---

[13] Hasbrouck (1988, 1991) also uses the signed proxies as the informational and inventory proxies.

give us some ideas about whether the values of trades have some impacts on the quotation behavior of the specialists.

The trading size indicator, ITQ, can capture the trade size effect suggested by information-based models, e.g., Easley and O'Hara (1987) and Laux (1993). If the quoted size of the transaction side represents a standard trading size in the concurrent trading period as suggested in Laux (1993), there appears to be an informed trade if the trade size is larger than the quoted size of the transaction side because this large trade size will signal the involvement of the informed traders. In the meantime, this variable could possibly seize the effects of the hidden limit orders situation investigated by McInish and Wood (1992)14 that states that the hidden limit orders not revealed to the public by specialists will result in the trading disadvantages of public traders and impede order placement strategies of the public traders.

From the discussions above, the $\beta_j'\mathbf{X}_i$ can be expressed as follows:

$$\begin{aligned}\beta_j'\mathbf{X}_i = {} & \beta_{1j}\, T\_Quote_i + \beta_{2j}\, NT_i + \beta_{3j}\, IBS_{i,t-1} + \beta_{4j}\, IBS_{i,t-2} + \beta_{5j}\, IBS_{i,t-3} + \\ & \beta_{6j}\, IBS_{i,t-1} \times DV_{i,t-1} + \beta_{7j}\, IBS_{i,t-2} \times DV_{i,t-2} + \beta_{8j}\, IBS_{i,t-3} \times DV_{i,t-3} + \\ & \beta_{9j}\, IBS_{i,t-1} \times ITQ_{i,t-1} + \beta_{10j}\, IBS_{i,t-2} \times ITQ_{i,t-2} + \beta_{11j}\, IBS_{i,t-3} \times ITQ_{i,t-3}\end{aligned} \quad (26)$$

Equation (26) presents the estimation equation in this research for the basic model and the detailed model. For the dollar trade size variables and the trade size indicator variables, we use the product of the transaction direction indicator and the associated variable in the same time period as our explanatory independent variable, because not only do the effects of those variables influence the choice of a specialist but also the transaction direction of a trade affects a specialist to change either side of a quote following the influences of those variables.

[14] McInish and Wood (1992) propose that the following problems on the NYSE will arise because of unrevealed hidden limit orders: (1)impede strategic decisions on order placement, (2) result in publicly submitted market orders receiving inferior prices, (3) hamper the monitoring of order executions, (4) reduce the probability of a limit orders being executed, (5) result in a delay in reporting limit-order executions, (6) interfere with the ability of the regional exchanges to execute public orders and (7) artificially improve NYSE performance relative to the regional exchanges using a common benchmark.

Empirical Results

The empirical results are shown from Tables 2 to 5. Table 2 shows the estimation results of β_1 for the ask move equation (AM) and the bid move equation (BM) in the basic model. For the AM equation, the median of β_1 in the AM equation is negative. This points out that most specialists will choose not only to move their ask prices but also to move their bid prices when the time between quote changes increase. Meanwhile, in the bid move equation, the median of β_1 is also negative. It means that most specialists will choose not to move their bid prices, when the time between quotes increases and might choose to move their bid prices, when the time between quotes decreases. Therefore, the results of the basic model for β_1 tell us that most specialists will not choose a one-sided move, i.e., to move the ask prices only or the bid prices only, when the time between quotes increases. Easley and O'Hara (1992) indicate that the time between trades is an informational factor providing the extra information we are unable to infer from the trading prices and trading volumes, and, therefore, the time will affect the volatilities and price sequences of securities. They predict that the ask prices and the bid prices will be adjusted toward their inferred prices, following the information deduced from the time factor. Hausman, Lo and MacKinlay (1992) and Fletcher (1995) advance their empirical evidence, confirming the predictions of Easley and O'Hara (1992). Consistent with their predictions, our empirical results of the AM and BM equations in the basic model about the time factor indicate that the time between quotes is one of major factors most specialists will consider, and specialists will not choose a one-sided move when the time between quotes increases. There may be two kinds of major reasons stimulating specialists to make changes when the specialists choose to change their quoted prices in a longer time interval between quote changes. The first is that there are informational events happening, and the second is that there are informational uncertainties being resolved during this interval. Since the time between quotes increases, these informational events will imply informational contents for the ask prices and the bid prices and cause specialists to adjust their risk premiums included in their ask prices and bid prices. On the other hand, if the specialists chose to change their quotes in a shorter time interval, they will choose a one-sided move, i.e., to move only the ask price or only the bid price, but not both. That means that the information the specialists have is only enough for them to move one side of the quoted prices in this short interval, or they will be exposed to larger adverse selection problems. Observing Tables 3 to 5 for the detailed model, we will find that all the medians of β_1 for AM_INC, AM_DEC, BM_INC, and BM_DEC are negative. These results of the detailed model reconfirm our inferences in the basic model that most specialists will choose to move their quoted ask prices and the quoted bid prices together when they change their quotes during a longer time gap. For the Both_Inc case of the time between quotes in the detailed model, the results show that most specialists will choose to reduce the probability of the choice of increasing both the ask prices and the bid prices. It suggests that if specialists change their quoted prices in a longer time gap between quote changes, they will choose to reduce both the ask prices and the bid prices with a slightly higher probability than to increase both the ask price and the bid price.

Table 2 The Coefficient Medians for the Ask Move and Bid Move Cases

	Ask Move (AM)	Bid Move (BM)
Tquote (β_1)	-0.3251	-0.3235
NT (β_2)	0.1946	0.2005
IBS_{t-1} (β_3)	0.2328	-0.2328
IBS_{t-2} (β_4)	-0.0581	0.088
IBS_{t-3} (β_5)	-0.0222	0.1203
$IBS_{t-1} \times DV_{t-1}$ (β_6)	0.1233	-0.0481
$IBS_{t-2} \times DV_{t-2}$ (β_7)	-0.0159	-0.0386
$IBS_{t-3} \times DV_{t-3}$ (β_8)	0.0706	0.0406
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	0.3075	-0.3119
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	0.0643	-0.1187
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	-0.0511	-0.1813

Regarding the trading intensity, Table 2 reports that the medians of β_2 are positive in the AM equation and in the BM equation of the basic model. Thus, we can understand that most specialists will choose a one-sided move when the number of trades between quotes increases. Consistent with the basic model, Tables 3 to 5 also show that medians of β_2 are positive. Since the inventory model (Garman (1976), and Amihud and Mendelson (1980)) suggests that the spread will be reduced if the specialist's inventory position is very close to his desired level, or be increased if the specialist's inventory position is far from his desired level. Therefore, the choice of the one-sided move of the specialists will make the spread change pattern as predicted by the inventory control model.

Moreover, as we mentioned before, in the information asymmetry model of Admati and Pfleiderer (1988), the concentration of the trading will better the trading terms of the uninformed traders because the competition among informed traders leads to a reduction of the spread. On the other hand, in the information asymmetry model of Spiegel and Subrahmanyam (1992), the concentration of the trading will worsen the welfare of the uninformed traders and lead to an increase of the spread because when the number of informed traders grows, the more the risk averse uninformed traders will scale back their trades. Consequently, the one-sided move of the specialists will indicate the informational effects as well when the trading activity increases. Therefore, the higher trading activity at a prevailing quote may concentrate on one side of the quoted prices and reveal information and cause inventory imbalance problems on that side of the quote. Then, the specialists will decide to change that side of the quote.

The transaction direction indicators will pinpoint the trade trend of the trading crowd. Table 2 reports that median of β_3 in the AM equation is positive while the median of β_3 of the BM equation is negative. It reveals that most specialists will choose to move their ask prices (bid prices) and not to move their bid prices (ask prices) when the previous transaction is buyer-initiated (seller-initiated). Consistent with the results of Hasbrouck (1988, 1991), the positive β_3 in the AM equation is agreeable with the information adjustment practices of the specialists. That is, the specialists will try to adjust their quotes based on the transaction trend of the previous transaction, since the concentration of trading in the buy (sell) side will imply extra information not reflected in the ask (bid) prices. Therefore, the ask (bid) prices should be revised to the prices the information reveals. Tables 3 to 5 show that the positive medians of β_3 are in the AM_INC, AM_DEC, and BM_INC equations, and the negative median of β_3 is in the BM_DEC equation. Thus, in general, the specialists will choose to increase or decrease the ask prices, or to increase the bid prices but not choose to decrease the bid price when the previous transaction is buyer-initiated. On the contrary, the specialists will choose to decrease their bid prices when the previous transaction is seller-initiated.

Table 2 shows that the median of β_6 for the AM equation is positive and the median of β_6 in the BM equation is negative. This means that most specialists will choose to move their ask prices when the previous trade has a larger dollar volume and is buyer-initiated. This is consistent with the informational findings of Easley and O'Hara (1987), Hasbrouck (1988, 1991), Hausman, Lo, and MacKinlay (1992), and Laux (1993) that the transaction with a larger trade size will have information content of security prices. In the meantime, the information will also be related to the side (ask or bid) at which the trade is completed.

Table 2 shows that the median of β_9 is positive in the AM equation and the median of β_9 is negative for the BM equation. This shows the same results as we see in the lag one transaction direction indicator. That means that the specialists will choose to move their ask (bid) prices when the previous trade size is larger than the quoted size of the ask (bid) side and is buyer-initiated (seller-initiated). In addition to confirming the arguments of Easley and O'Hara (1987), Hasbrouck (1988, 1991), Hasuman, Lo, and MacKinlay (1992), and Laux (1993), this also indirectly points out that trading volume will cause a positive relationship between the trading volume and the price variability.

Table 3 The Coefficient Medians for the Ask Increase and Decrease Cases

	Ask Increase (AM_INC)	Ask Decrease (AM_DEC)
Tquote (β_1)	-0.255	-0.3438
NT (β_2)	0.2563	0.2009
IBS_{t-1} (β_3)	1.0942	0.2712
IBS_{t-2} (β_4)	-0.1662	-0.0911
IBS_{t-3} (β_5)	-0.083	0.0498
$IBS_{t-1} \times DV_{t-1}$ (β_6)	0.1704	0.1266
$IBS_{t-2} \times DV_{t-2}$ (β_7)	-0.0415	-0.0636
$IBS_{t-3} \times DV_{t-3}$ (β_8)	0.038	-0.0296
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	0.6137	0.5375
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	-0.0437	0.2179
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	-0.156	0.0946

Table 4 The Coefficient Medians for the Bid Increase and Decrease Cases

	Bid Increase (BM_INC)	Bid Decrease (BM_DEC)
Tquote (β_1)	-0.4347	-0.2238
NT (β_2)	0.2159	0.2436
IBS_{t-1} (β_3)	0.7755	-0.1497
IBS_{t-2} (β_4)	-0.0715	0.0465
IBS_{t-3} (β_5)	0.0430	0.0830
$IBS_{t-1} \times DV_{t-1}$ (β_6)	0.0893	0.0923
$IBS_{t-2} \times DV_{t-2}$ (β_7)	-0.0626	-0.0494
$IBS_{t-3} \times DV_{t-3}$ (β_8)	-0.0592	-0.0539
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	0.1328	0.0589
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	-0.1416	0.1268
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	-0.2540	-0.1290

Table 5 The Coefficient Medians for the Both Increases Case

	Both Increases (BOTH_INC)
Tquote (β_1)	-0.1259
NT (β_2)	0.0895
IBS_{t-1} (β_3)	0.9804
IBS_{t-2} (β_4)	-0.1258
IBS_{t-3} (β_5)	-0.0862
$IBS_{t-1} \times DV_{t-1}$ (β_6)	0.1927
$IBS_{t-2} \times DV_{t-2}$ (β_7)	0.0475
$IBS_{t-3} \times DV_{t-3}$ (β_8)	-0.0476
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	0.6112
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	0.0546
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	0.0521

3.2 Empirical Results of the Quote Price and Size Decision

Data Description and Methodology

Using the same database we use in the previous section, we retrieve the quoted prices and the quoted sizes from the consolidated quote file, and transaction data from the consolidated trade file. In contrast to definition of the quote revision in the previous section, here we define quote revision as a change in any of the quote components, i.e., the bid price, the ask price, the bid size, or the ask size. Through this definition, we augment our quote data files and screen the data as we did in the previous section.

Our main object is to investigate how a specialist decides to change his quoted prices and quoted sizes when observing the trading activity and the information flow in the market. From the discussion of the theoretical model in the previous section and the findings and suggestions of Lee, Mucklow, and Ready (1993) and Charoenwong (1995), a specialist makes price and size choices simultaneously, based on all the information he has during the trading session. Since the decisions of the quoted prices and the quoted sizes are simultaneous, we employ the bivariate probit model.

The bivariate probit model is a natural extension of the probit model, including one more equation in the estimation process. For the ask side, we suppose that a specialist chooses to increase the ask price ($y_{1a} = 1$) if his reservation price movement ($y_{1a}^* > 0$) or chooses to decrease the ask size ($y_{2a} = 1$) if his reservation size movement ($y_{2a}^* < 0$). Therefore, assuming the joint distribution between these two choices is normal with a correlation coefficient ρ, the bivariate joint probability can be expressed as follows:

$$P(y_{1a} = 1,\, y_{2a} = 1) = \Phi(\beta_1'\mathbf{x}, \beta_2'\mathbf{x}, \rho) \tag{27}$$

Where β_1' and β_2' are coefficients, $\mathbf{x}$ represents the explanatory variables, and Φ is a bivariate normal distribution function with zero means, unit variances, and correlation ρ.[15] The log likelihood function of (27) is the following:

$$\log L = \sum_{i=1}^{n} \Phi(\beta_{i1}'\mathbf{x}, \beta_{i2}'\mathbf{x}, \rho) \tag{28}$$

In the same fashion, for the bid side, we also can set that a specialist chooses to decrease the bid price ($y_{1b} = 1$) if his reservation price movement ($y_{1b}^* < 0$) or chooses to decrease the ask size ($y_{2b} = 1$) if his reservation size movement ($y_{2b}^* < 0$). From the model setting above, we have two estimation models: (1) the ask price and the ask size model, and (2) the bid price and the bid size model. We estimate these two models respectively for each company. The estimation results are shown in the next section.

Empirical Results

Table 6 reports parameter estimates of the bivariate probit model for the ask price and ask size. We see that the median of β_1 is significantly positive for the AM_INC and the ASM_DEC equations. That means that specialists choose to increase their ask prices and decrease their ask sizes when they alter quotes in a long time gap between quote changes. As we noted, when examining the quoted price changes, there may be some unexpected informational events or some informational uncertainties being resolved during this time interval. Regarding the effects of the number of trades between quotes, the medians of β_2 are negative in the AM_INC and ASM_DEC equations. This reveals that the specialists choose to maintain current market liquidity or increase ask side liquidity by decreasing ask prices and increasing ask sizes when trading intensity increases. Therefore, since the competition between informed traders results in more information leakage during the trades, the specialists can confidently increase liquidity of the market without losing much to the informed traders. The medians of β_3 are positive in the AM_INC and the ASM_DEC equations, which indicates that the specialists choose to reduce the market liquidity, i.e., increase the ask prices and decrease the ask sizes, when the previous single trade is buyer-initiated.

---

15 ρ is the correlation coefficient as well under the normal distribution structures of error terms.

Regarding the effects of the dollar trade size variables, we find that signs of parameter medians are the same as those of the corresponding lag variables in the transaction direction indicators. As for the trade sizes, we find that the sign of the median of β_9 is positive in the AM_INC equation but negative in the ASM_DEC equation. This shows that most specialists tend to increase their ask prices when the lag one trade size is larger than the quoted size and is buyer-initiated. Compared with effects of the lag one trade size indicator, the effects of the lag two and the lag three trade size indicators will be smaller.

Table 7 reports the parameter estimates of the bivariate probit model for the bid price and the bid size model. We find that the medians of β_1 in the BM_DEC Table 6

Table 6 The Coefficient Medians for the Ask Price and Ask Size Cases

	Ask Increase (AM_INC)	Ask Size Decrease (ASM_DEC)
Tquote (β_1)	0.2375	0.1816
NT (β_2)	-0.4221	-0.2603
IBS_{t-1} (β_3)	0.2600	0.2082
IBS_{t-2} (β_4)	-0.0830	0.0900
IBS_{t-3} (β_5)	-0.0943	0.0042
$IBS_{t-1} \times DV_{t-1}$ (β_6)	0.04600	0.0774
$IBS_{t-2} \times DV_{t-2}$ (β_7)	-0.0773	0.0590
$IBS_{t-3} \times DV_{t-3}$ (β_8)	-0.0695	0.0458
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	0.3605	-0.2942
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	0.1153	-0.2406
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	0.1680	-0.2641

Table 7 The Coefficient Medians for the Bid Price and Bid Size Cases

	Bid Decrease (BM_DEC)	Bid Size Decrease (BSM_DEC)
Tquote **(** β_1 **)**	0.2400	0.1868
NT (β_2)	-0.4582	-0.2594
IBS_{t-1} (β_3)	-0.2969	-0.1961
IBS_{t-2} (β_4)	-0.0379	-0.0920
IBS_{t-3} (β_5)	-0.0592	-0.0746
$IBS_{t-1} \times DV_{t-1}$ (β_6)	-0.0776	-0.0796
$IBS_{t-2} \times DV_{t-2}$ (β_7)	-0.0639	-0.0489
$IBS_{t-3} \times DV_{t-3}$ (β_8)	-0.0383	-0.0365
$IBS_{t-1} \times ITQ_{t-1}$ (β_9)	-0.3795	0.3094
$IBS_{t-2} \times ITQ_{t-2}$ (β_{10})	-0.2107	0.1695
$IBS_{t-3} \times ITQ_{t-3}$ (β_{11})	-0.1736	0.2306

and BSM_DEC are positive. This shows that most specialists choose to decrease their bid prices and bid sizes when they change their quotes in a long trading gap. Consistent with the ask price and the ask size model, the longer time between quotes, the more chances for the unexpected informational events or uncertainties to occur. The medians of β_2 in the BM_DEC and the BSM_DEC equations are negative. This indicates that specialists maintain or increase the bid side liquidity of market by increasing the bid prices and bid sizes when trading intensity increases. Combining the results above with the ask price and the ask size model, we find that the specialists maintain or increase the market liquidity by increasing quoted sizes and decreasing the spread. This seems to contradict the U-shape trading pattern found by empirical researchers, such as Wood, McInish, and Ord (1985), Harris (1986), and McInsih and Wood (1990). Empirical studies (Jain and Joh (1988) and McInish and Wood (1990), and Foster and Viswanathan (1993)) have found that there are larger trade sizes and trade volumes at the open and the close of the stock market. As suggested by McInish and Wood (1992), the joint effect of information, trading activity, and competition is indeterminate, given the trading properties at the beginning and the end of the trading day. Therefore, from the empirical results shown here, we find that specialists decrease market liquidity heavily, depending on a given most recent trade itself, such as trade direction and trade size. Higher trading intensity brings more informational and more inventory control advantages to the specialists.

The negative medians of β_3 are shown in the BM_DEC and BSM_DEC equations indicate that the specialists decrease the bid prices and bid sizes when the previous single trade is seller-initiated. Meanwhile, for the effects of the lag one trade size indicator, we find that the median of β_9 is negative in the BM_DEC equation but positive in the BSM_DEC equation. This indicates that most specialists would decrease their bid prices when the previous single trade size is larger than the quoted size and is seller-initiated.

IV. Conclusion

We examine the choice decision of the specialist regarding the quote prices and quoted sizes. Consistent with Easley and O'Hara (1992), Hausman, Lo, and MacKinlay (1992), and Fletcher (1995), the longer time between quotes signals some information uncertainty will happen and causes the specialists to move both sides of the quote simultaneously. The quoted prices tend to decrease in a higher probability than to increase. On the contrary, the specialists move only one side of the quote in the shorter time gap between quotes. The reason for the one-sided move may be that they have information only for one side.

The higher trading intensity will cause the specialists to choose a one-sided move, i.e., change the ask price only or the bid price only, because the more active trading indicates a higher possibility of a larger number of informed traders and the uninformed traders trading intensively on the one side of the prevailing quote and reveals the information asymmetry and inventory control consideration to the specialist. Thus, the specialists will choose to move one side of the quote. For the transaction indicators, we find that the lag one transaction indicator is a significant informational indicator that will cause the specialists to move the ask (bid) price when the lag one transaction is buyer-initiated (seller-initiated). In the meantime, the specialists tend to reduce their bid prices when the lag one transaction is seller-initiated. Meanwhile, like the lag one transaction indicator, the lag one trade size has significant effects on the quote decision of the specialists, and the specialists will try to move their ask (bid) prices when the lag one trade size is large and buyer-initiated (seller-initiated).

Unlike the previous studies casting notices on the spreads and arguments of Jang and Venkatesh (1991), we investigate the choice behaviors of the specialists and find that the quote-revision behaviors of the specialists will be affected by the information asymmetry and inventory control factors. Meanwhile, the results show that the most recent trade affects the quote decision of the specialists more, while the trades with more than one lag do not have important effects.

Furthermore, we have developed a theoretical model explaining the quoted prices and quoted sizes decisions of the specialists and adopt the bivariate probit model to investigate the simultaneous decisions about quoted prices and sizes. Empirical results indicate that information does affect the quoted price and size decision of the specialists. There are some informational uncertain events happening during the longer time gap between two different quotes, which causes the specialists to decrease the market liquidity either on the ask side or the bid side. The more intensive trading causes the specialist to maintain or increase the market liquidity, i.e., increase the bid price (decrease the ask prices) and increases the bid (ask) size. The specialists decrease market liquidity when the most recent single trade contains informational disadvantages to them. Thus, when the most recent trade size is much larger than quoted size and is buyer-initiated (seller-initiated), the specialists increase the ask prices (decrease the bid prices) and decrease the ask (bid) sizes.

Consistent with the findings of Lee, Mucklow, and Ready (1993), the empirical results show that the information asymmetry risks cause the specialists to reduce the market liquidity. Also, we confirm that the most recent trade carries most of security information to which the specialists would react.

References

Admati, Anat R. and Paul Pfleiderer. 1988. A Theory of Intraday Patterns: Volume and Price Variability. *Review of Financial Studies* ,1:3-40.

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

Amihud, Yakov and Haim Mendelson. 1980. Dealership Market: Market-Making with Inventory. *Journal of Financial Economics*, 8:31-53.

Bagehot, Walter. 1971. The Only Game in Town. *Financial Analyst Journal*, 22, 12-14.

Benston, Geroge J. and Robert L. Hagerman. 1974. Determinants of Bid-Asked Spreads in the Over-The-Counter Market. *Journal of Financial Economics*, 1: 353-364.

Chareonwong, Charlie. 1995. Essays on the Stock Market Micorstructure: I. An Analysis of Quoted Depths for NYSE and AMEX Stocks; II. Insider Trading and the Bid-Ask Spread. Unpublished Ph.D. dissertation, University of Memphis.

Cheng, Minder and Ananth Madhavan. 1994. In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets. *Working Paper #94-02*, NYSE.

Chiang, Min-Hsien. 2001. The Information Transmission between the Stock Market and the Options Market- The Case of IBM. Sun Yat-Sen Management Review, 9: 19-47.

Chiang, Min-Hsien and Yun Lin. 2003. Investigating the Bid-Ask Spread Components between the NYSE and the CBOE. forthcoming, *Advances in Quantitative Finance and Accounting*.

Copeland, Thomas E. and Dan Galai. 1983. Information Effects on the Bid-Ask Spread. *Journal of Finance*, 38, 1457-1469.

Easley, David and Maureen O'Hara. 1987. Price, Trade Size, And Information in Securities Markets. *Journal of Financial Economics*, 19: 69-90.

Easley, David and Maureen O'Hara. 1992. Time and the Process of Security Price Adjustment. *Journal of Finance*, 47: 577-605.

Fletcher, Roy A. 1995. The Role of Information and the Time Between Trades: An Empirical Investigation. *Journal of Financial Research*, 18: 239-260.

Foster, Dougla F. and S. Viswanathan. 1990. A Theory of the Interday Variation in Volume, Variance, and Trading Costs in Securities Markets. *Review of Financial Studies*, 3: 593-624.

Foster, Dougla F. and S. Viswanathan. 1993. The Effect of Public Information and Competition on Trading Volume and Price Volatility. *Review of Financial Studies*, 6: 23-56.

Garman, Mark B. 1976. Market Microstructure. *Journal of Financial Economics*, 3: 257-275.

Glosten, Lawrence R. and Paul R. Milgrom. 1985. Bid, Ask and Transaction Prices in A Specialist Market with Heterogeneouly Informed Traders. *Journal of Financial Economics*, 14: 71-100.

Harris, Lawrence. 1986. A Transaction Data Study of Weekly and Intradaily Patterns in Stock Returns. *Journal of Financial Economics*, 16: 99-117.

Harris, Lawrence. 1990. Statistical Properties of the Roll Serial Covariance Bid/Ask

Spread Estimator. *Journal of Finance*, 45: 579-590.

Hasbrouck, Joel. 1988. Trades, Quotes, Inventories, and Information. *Journal of Financial Economics*, 22: 229-252.

Hasbrouck, Joel. 1991. Measuring the Information Content of Stock Trades. *Journal of Finance*, 46: 179-207.

Hasbrouck, Joel. 1992. Using the TORQ Database, Stern School of Management, New York University.

Hasbrouck, Joel. 1995. One Security, Many Markets: Determining the Contributions to Price Discovery. *Journal of Finance*, 50: 1175-1199.

Hausman, Jerry A., Andrew W. Lo, and A. Craig MacKinlay. 1992. An Ordered Probit Analysis of Transaction Stock Prices. *Journal of Financial Economics* ,31: 319-379.

Jain, Prem C. and Gun-Ho Joh. 1988. The Dependence between Hourly Prices and Trading Volume. *Journal of Financial and Quantitative Analysis*, 23:269-283.

Jang, Hasung and P. C. Venkatesh. 1991. Consistency between Predicted and Actual Bid-Ask Quote-Revisions. *Journal of Finance*, 46: 433-446.

Kyle, Albert S.1985. Continuous Auctions and Insider Trading. *Econometrica*, 53: 1315-1335.

Laux, Paul A. 1993. Trade Sizes and Theories of the Bid-Ask Spread. *Journal of Financial Research*, 16: 237-249.

Lee, Charles M., Belinda Mucklow, and Mark J. Ready. 1993. Spreads, Depths, and the Impact of Earnings Information: An Intraday Analysis. *Review of Financial Studies*, 6: 345-374.

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

McInish, Thomas H. and Robert A. Wood. 1990. A Transactions Data Analysis of the Variability of Common Stock Returns During 1980-1984. *Journal of Banking and Finance*, 14: 99-112.

McInish, Thomas H. and Robert A. Wood. 1992. An Analysis of Intraday Patterns in Bid/Ask Spreads for NYSE Stocks. *Journal of Finance*, 47: 753-764.

Seppi, Duane J. 1990. Equilibrium Block Trading and Asymmetric Information. *Journal of Finance*, 45: 73-94.

Seppi, Duane J. 1992. Block Trading and Information Revelation around Quarterly Earnings Announcement. *Review of Financial Studies*, 5: 281-305.

Spiegel, Matthew and Avanidhar Subrahmanyam. 1992. Informed Speculation and Hedging in a Noncompetitive Securities Market. *Review of Financial Studies*, 5: 307-329.

Stoll, Hans R. 1989. Inferring the Components of the Bid-Ask Spread: Theory and Empirical Tests. *Journal of Finance*, 44: 115-134.

Subrahmanyam, Avanidhar. 1991. Risk Aversion, Market Liquidity, and Price Efficiency. *Review of Financial Studies*, 4: 417-441

Wood, Robert A., Thomas H. McInish, and J. Keith Ord. 1985. An Investigation of Transactions Data for NYSE Stocks. *Journal of Finance*, 40: 723-739.

About the Author

Min-Hsien Chiang

Dr. Chiang received his Ph.D. from Syracuse University, USA, and currently serves as associate professor of Finance at the Institute of International Business, National Cheng Kung University, TAIWAN. His research interests include market microstructure, financial econometrics, and nonstationary panels. Meanwhile, he is also one of major developers working on the NPT (Nonstationary Panel Time Series) package in GAUSS. His research papers have been published in Advances in Econometrics, Advances in Quantitative Analysis of Finance and Accounting, Applied Economics, Applied Economics Letters, Applied Financial Economics, Economics Bulletin, Global Finance Journal, International Journal of Business and Economics, Oxford Bulletin of Economics and Statistics, Review of Securities and Futures Markets, Sun Yat-Sen Management Review and PanPacific Management Review.