Bid-Ask Spreads in Multiple Dealer Settings: Some Experimental Evidence

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Abstract: We report the results of an experiment designed to investigate the behavior of quoted spreads in multiple-dealer markets. We manipulate verbal communication (not allowed and allowed) and order preferencing (not allowed, allowed, and allowed with order-flow payment) between eighteen sessions. Without preferencing, spreads are wider when communication is allowed. With preferencing (and no order-flow payments), individuals do not have incentives to narrow the spread and a wide spread may be maintained without a collusive agreement. However, spreads narrow somewhat when individuals are given the opportunity to compete using alternatives to price (that is, payment for order flow).

JEL classification: G10, G18

Key words: bid-ask spread, preferencing, collusion

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BID-ASK SPREADS IN MULTIPLE DEALER SETTINGS: SOME EXPERIMENTAL EVIDENCE

In this paper we use an experimental economics method to examine bid-ask spreads in multiple dealer settings. Important multiple dealer markets include the stock market made by the National Association of Securities Dealers Automated Quotation (NASDAQ) system and the London Stock Exchange. These markets are expected to produce narrow spreads through competition among dealers for order flow. While multiple dealer markets rely on competitive forces to discipline dealers, such forces may be counterbalanced by dealers' abilities to communicate when setting spreads. Christie and Schultz (1994) and Christie, Harris, and Schultz (1994) suggest that dealers in the NASDAQ market implicitly collude to maintain wide spreads. However, tacit collusion is not the only explanation for the empirical phenomenon reported in these articles.

Wide spreads may arise from the features of a particular market structure which reduce dealers' incentives to price competitively. On NASDAQ, dealers internalize or preference a substantial portion of the order flow. That is, a dealer trades with a customer for the dealer's account or forwards the order to another market maker who fills the order at the best price quote. Godek (1996), Huang and Stoll (1996), and Kandel and Marx (1997a) conclude that a dealer's ability to internalize or preference order flow is an important factor that affects the dealer's quoted spreads. This market feature limits incentives to quote narrow spreads because dealers do not compete over incoming orders through their price quotes. However, it is also recognized that dealers use other cash and noncash methods to compete for order flow (Dutta and Madhaven, 1997; Hansch, Naik, and Viswanathan, 1997; and Kandel and Marx, 1997b). For example,

dealers frequently pay brokers for order flow, particularly if the spread exceeds the marginal cost of making a market in the stock.

We use an experimental economics method to examine the effects of verbal communication and order preferencing on quoted spreads in multiple dealer settings. The distinction between implicit and overt collusion is important given the different antitrust implications. Our method allows us to isolate the effects of communication and preferencing on observed spreads, an investigation that cannot be conducted in naturally occurring markets. In addition, the experimental method allows us to control factors extraneous to the investigation, which although important, create the potential for confounds when using archival data. Our results complement those of prior studies using archival data and shed light on the direct effects of communication and preferencing on quoted bid-ask spreads. Furthermore, our method allows us to examine how dealer behavior is affected when dealers can compete using other mechanisms in addition to price. In particular, we examine settings in which dealers can pay for order flow to attract clients.

We find that in settings without preferencing, spreads are wider when communication is permitted. In settings with preferencing, spreads are even wider, regardless of whether communication is allowed. However, when dealers are given the opportunity to compete for order flow using alternatives to price, behavior is affected. We find that dealers are willing to pay for order flow and spreads narrow, though they are not as narrow as spreads observed without preferencing. Hence, our results suggest that preferencing is an important consideration when policy makers attempt to evaluate the efficiency and competitiveness of dealer markets with the caveat that other institutional features can have a significant impact.

This paper is organized as follows. Section 1 provides a framework for our subsequent empirical investigation. Section 2 describes the experimental procedures, and Section 3 presents the empirical results. Section 4 offers discussion and concluding remarks.

1. Framework

In dealer markets, orders are filled at the best bid or ask price. Competition among dealers is thought to produce narrow bid-ask spreads. In a Bertrand equilibrium, competition is expected to drive the spread to the marginal cost of trading (Glosten and Milgrom, 1985). For an actively traded issue on NASDAQ, upwards of 30 dealers participate in determining the spread. However, Christie and Schultz (1994) and Christie, Harris, and Schultz (1994) allege that dealers in these markets collude to widen spreads. Christie and Schultz report that odd-eighth quotes are almost nonexistent for many actively traded NASDAQ stocks and suggest that NASDAQ market makers implicitly collude to widen spreads. The implicit pricing agreement seems to have fallen apart once Christie and Schultz's findings were reported in national newspapers. Christie, Harris, and Schultz report the sudden and extreme change in spreads for five actively traded issues and the concomitant increase in the use of odd-eighth quotes for these stocks. However, neither study demonstrates that the spreads observed in the NASDAQ market are, in some sense, too wide.

Some have disputed the conclusion that NASDAQ dealers implicitly collude to maintain wide spreads (see e.g., Kleidon and Willig, 1995; and Laux, 1995). The empirical evidence reported by Kleidon and Willig (1995) suggests that competitive economic factors can explain the frequency of odd-eighth quotes on both NASDAQ and the NYSE. Furthermore, the width of spreads on NASDAQ stocks that frequently quote on even-eighths is no different from that of

stocks that frequently quote on odd-eighths (Laux, 1995). The structure of the NASDAQ market makes collusion extremely difficult to maintain. In particular, market makers face few, if any, barriers to entry, the market includes a large number of market makers with a diversity of incentives, and plausible sanctions for violators of collusive agreements are lacking.

Until a recent article by Huang and Stoll (1996), no empirical study had clearly established how spreads differ, if at all, across various market structures. Huang and Stoll compare spreads for carefully matched samples of NASDAQ and NYSE firms. They find that spreads are wider for the NASDAQ sample and that the spreads on NASDAQ have increased over time. Many possible sources of the divergence in spreads can be ruled out, notably, differences across firm characteristics and the frequency of odd-eighth price quotes. Huang and Stoll (1996) and Godek (1996) conclude that likely sources for the observed spread patterns are preferencing and internalization in the NASDAQ market. Though preferencing and internalization are also possible on the NYSE, this institutional arrangement is more prevalent on NASDAQ. When orders are preferenced or internalized, the dealer who receives the order fills it at the best inside price quote.[1] The result is that dealers have little incentive to narrow the spread. A dealer's share of the order flow cannot be increased by narrowing the spread if most orders are preferenced. Huang and Stoll suggest that the frequency of preferencing has increased over time, though they do not have direct evidence to support this assertion. The evidence reported by Huang and Stoll and Godek suggests that wide spreads on NASDAQ result from the particular market structure, rather than from implicit collusion among market makers.

Models of dealer markets that explicitly consider institutional features of the NASDAQ market have been proposed. Incorporating price discreteness and preferencing, Kandel and Marx

(1997a) find that competition does not necessarily drive the spread to the marginal cost of trading. Instead, the equilibrium spread may not be driven below the marginal cost of trading plus two times the price tick. When preferenced trades are included in their model, market makers have even less incentive to reduce the spread. The use of a focal point, such as even-eighth quotes, as a coordination device permits market makers to choose through interaction over time one of the competitive equilibria without the need for communication.[2] This focal-point equilibrium does not rule out collusion but permits market makers to choose the largest competitive spread and generate profits similar to the profits possible with a collusive agreement.

Dutta and Madhaven (1997) show that even dealers who act noncooperatively can set bid-ask spreads above competitive levels. Institutional features, like order preferencing, are important determinants of the spread. Price discreteness is not required. In addition, their analysis shows that even if dealers fail to compete over price as a result of preferencing, dealers may compete other ways. Non-price competition can take the form of vertical agreements with brokers in which dealers agree to pay brokers for order flow. Importantly, Dutta and Madhavan distinguish implicit from explicit collusion. Implicit collusion occurs when dealers who act noncooperatively accrue abnormal profit whereas explicit collusion suggests cooperation among market makers. This distinction is critical for policy discussion because implicit collusion is not necessarily illegal.

In this study we directly examine the effects of communication and preferencing on quoted spreads in multiple dealer settings. An experimental economics method allows us to regulate overt communication among dealers and govern institutional features, while isolating the effects of the variables of interest. If dealers are not permitted to communicate verbally and in the absence of preferenced order flow, bid-ask spreads should be determined by competitive forces.

However, if dealers are inclined to overtly collude in setting spreads when permitted to communicate verbally, we expect to observe bid-ask spreads that are wider than predicted under competition. In addition, if preferencing reduces incentives to compete, we expect to find higher spreads in settings with preferencing, regardless of whether dealers are able to communicate. Finally, if preferencing reduces dealers' incentives to compete on price, we expect to find that dealers are willing to compete on non-price dimensions to attract clients (e.g., through payment for order flow).

2. Experimental Procedures

We examine bid-ask spreads in six experimental settings. In constructing the settings, we manipulate verbal communication (not allowed and allowed) and preferencing (not allowed, allowed, and allowed with order flow payment). We conduct three sessions for each of the six experimental settings, giving a total of 18 sessions. The design is summarized in Table 1.

At the beginning of each session participants receive a set of instructions that are read aloud.[3] We recruit participants from third- and fourth-year, undergraduate students in business and economics and M.B.A. students at two universities. Participants have taken at least one finance course, with an average of 3.07 finance courses (including courses in which they are currently enrolled). Thus, participants are aware that stock prices are commonly expressed in ticks and familiar with the concept of bid-ask spread. Four participants take part in each session and all participants are inexperienced in that they have not participated in an earlier session. Across the 18 sessions, participants earn an average of $30.00 for participating approximately 90 minutes.

Each experimental session consists of 24 periods. In the nine sessions with verbal communication, participants are informed that they are free to confer with other participants at any time. In the nine sessions without communication, participants are informed that they should not confer with other participants at any time. The instruction concerning verbal communication is reinforced repeatedly in all sessions.

At the beginning of each session, participants are informed that they will make a market in a firm's stock. In sessions with preferencing (with and without order flow payments), they also act as brokers for their clients. Participants are endowed with 200 shares of a firm's stock and $10,000. Each period participants are asked to submit prices at which they are willing to buy (P^B) and sell (P^A) the firm's stock. Participants are informed that outside investors place orders to buy and sell the stock. The distribution of price offers is known and constant across periods and sessions. Prices are always expressed in increments of one-eighth. Offers to buy from participants (P^{OB}) may take values in the interval from $25 to $26 7/8 and their distribution is given by

$$prob(P^{OB} = p(y)) = \frac{17 - y}{136} \qquad (1)$$

where p(y) = 25, 25 1/8, 25 2/8, ..., 26 7/8 for y = 1, 2, 3, ..., 16. Offers to sell to participants (P^{OS}) are distributed in the interval from $23 1/8 through $25 and their distribution is given by

$$prob(P^{OS} = p(y)) = \frac{y}{136} \qquad (2)$$

where p(y) = 23 1/8, 23 2/8, 23 3/8, ..., 25 for y = 1, 2, 3, ..., 16. Rather than representing each probability distribution by means of a formula, the experimental instructions include probability histograms for the two distributions.

Each order to buy or sell is for 10 shares except in sessions with payment for order flow. In these sessions, participants are instructed that they can pay a "rebate" to their clients in return for their orders and, in turn, increase the orders received. Rebates are reported in increments of one cent per share, can take any nonnegative value, and are set before bid and ask prices are revealed. In sessions with order flow payment, participants may compete on this non-price dimension because the individual(s) submitting the best rebate is (are) successful in attracting clients. If one market maker alone submits the best (highest) rebate, that individual's orders are for 20 shares each while all other's orders are for 10 shares. If two market makers submit the best rebate, their orders are for 15 shares each. If three individuals submit the best rebate, each order received by those three individuals is for 12 shares. If all market makers submit the same rebate, all orders are for 10 shares. The best rebate determines the market rebate and all participants compensate their clients similarly.[4]

After group members determine bid and ask prices, participants reveal their prices to the group. The best (lowest) ask and (highest) bid prices determine the prices at which orders to buy and sell are filled. In sessions with payment for order flow, all participants also reveal their rebate and the market rebate is determined. Each period the group receives from one to four orders to buy and one to four orders to sell. The number of orders to buy and sell is determined

independently and randomly prior to the experimental sessions by the experimenters using uniform distributions.[5] Order prices are randomly and independently determined using the distributions expressed in equations (1) and (2). Participants are informed that they must stand ready to accept offers to sell shares at their bid price and offers to buy shares at their ask price. Orders are always filled at the best bid and ask prices. Orders can go unfilled because the orders are at prices below the market ask or above the market bid.[6]

In the six sessions without preferencing, orders to buy and sell are filled by the individual(s) with the best bid and ask prices.[7] In the event that two or more participants announce identical bid or ask prices, orders are evenly divided. In the 12 sessions with preferencing, participants receive a card detailing the orders for the firm's stock placed by their clients each period. Participants can choose to fill the orders at the best bid and ask prices or pass them on to the individual(s) who set the spread. The set of orders received by all participants is identical to that received by the market in the absence of preferencing.

At the end of each session, participants return the endowment of 200 shares and $10,000. If they hold less than 200 shares, the deficit can be purchased for $25. Any shares held in excess of 200 are sold to the experimenters at the same price. Participants incur no costs when carrying or replenishing inventory as offers to buy are always at prices equal to or above $25 and offers to sell are always equal to or below $25.[8] All earnings are converted to dollars at a predetermined exchange rate. Participants are paid in cash as they complete a post-experiment questionnaire, which includes two open-ended questions to probe (1) the process used in determining bid and ask prices and (2) the nature of cooperation among participants in setting prices. In sessions with payment for order flow, we also asked participants an open-ended question concerning

cooperation in setting rebates. To provide participants with an incentive to respond conscientiously, we pay them $2.00 for completing the questionnaire.[9]

3. Results

Panel A of Table 2 reports the spread per period for each of the six sessions without preferencing.[10] First we examine the spread for sessions in which verbal communication is forbidden. Using data from periods 1-24, the average spread across the three sessions ranges from $0.22 to $0.41. Using data from periods 7-24 (13-24), the average spread ranges from $0.22 to $0.24 ($0.19 to $0.25). We compute the mean spread excluding data from periods 1-6 (and 1-12) because, in some sessions, the spread is quite volatile across the earlier periods of the experiment.[11] Notably, in all three sessions the spread settles down to a level that is close to the competitive spread: two times the tick size plus the marginal cost of trading. In our experimental setting, the tick size is 1/8 and the marginal cost of trading is zero, which results in a competitive spread of $0.25.

Next we examine the spread for sessions without order preferencing in which verbal communication is permitted. The observed spread appears to be larger in sessions with communication as compared to those without.[12] In sessions 4 and 6, the spread settles down to a level that is slightly above that in sessions without communication ($0.29 and $0.50). In session 5, the observed spread is much larger ($1.33).

Panel B of Table 2 reports the spread per period for each of the six sessions with preferencing (without payment for order flow). Without verbal communication (sessions 7-9), the average spread is in excess of $0.80 using data from periods 1-24, 7-24, and 13-24. Bid-ask

spreads are wider in sessions with preferencing than in those without preferencing when verbal communication is not permitted.

Further inspection of Panel B suggests that the mean spread does not differ much across sessions with and without communication when orders are preferenced. The observed spread exceeds \$0.80, regardless of whether verbal communication is permitted. Thus, when preferencing is allowed, verbal communication does not appear to affect the spread.

The final panel of Table 2 reports the spread per period for the six sessions with preferencing and payment for order flow (sessions 13-18). For these sessions the average spread appears to settle to a level exceeding the competitive spread, but lower than the average spread observed in sessions with preferencing and no payment for order flow (sessions 7-12). Across the sessions with and without communication, there seems to be some increase in spreads with communication. We also note that dealers are willing to pay for order flow. The average rebate in the three sessions without (with) communication is 19.8¢ (10.1¢). These averages are significantly different at $p < 0.01$ ($t = -6.56$),

To conduct formal statistical tests, we perform an analysis of variance (ANOVA). The independent variables include communication, preferencing, and the interaction term. The communication variable takes two levels (without and with) and the preferencing variable takes three levels (without, with, and with along with payment for order flow). The dependent variable is the spread per period. The ANOVA results, shown in Table 3, indicate that all three independent variables are significant at $p < 0.01$.[13, 14]

Because the interaction term is significant, we perform additional analyses to investigate the simple effects of communication and preferencing on the observed spread. First, we examine

the simple effect of communication. We perform three ANOVAs where the independent variable is communication and the dependent variable is the spread per period. The results are reported in Panels A, B, and C of Table 4. Using data from the six sessions in which preferencing is not allowed, we find that communication is significant at $p < 0.001$. Using data from the six sessions in which preferencing is allowed (with no payment for order flow), we find that communication is not significant at any conventional level ($p = 0.213$). Finally, using data from the six sessions with preferencing and payment for order flow, we find that communication is significant at $p < 0.001$. Hence, communication widens the spread, but only when dealers have incentives to compete using price or an alternative method such as order flow payment.

Next we examine the simple effect of preferencing. We perform two ANOVAs: one using data from the nine sessions with communication and one using data from the nine sessions without communication. In each case, the independent variable is preferencing and the dependent variable is the spread per period. The results, shown in Panels A and B of Table 5, indicate that in both cases preferencing is significant at $p < 0.001$. Thus, preferencing widens the spread, regardless of whether communication is allowed.

To gain additional insight into dealer behavior, we examine participants' responses to the following open-ended question: how would you characterize the process by which you decided on your quoted bid and ask prices? A sample response from each experimental session is reported in Table 5. Reported responses are representative of those of the majority of group members in the same session. When preferencing is allowed, participants' responses seem to focus on setting a spread that provides an acceptable return: that is, achieving a tradeoff between the number of orders filled and the profit per transaction (refer to Panels C, D, E, and F). When preferencing is

not allowed, participants' responses seem to vary depending on whether verbal communication is permitted. With communication, participants suggest that collusion occurs (refer to Panel B). Without communication, participants suggest that competitive forces drive prices (refer to Panel A).

We also examine participants' responses to a second open-ended question: how would you characterize cooperation observed during the experiment? A sample response from each session is reported in Table 7. As before, reported responses are representative of the majority of group members in the same session. When preferencing is allowed, some degree of "loose" cooperation appears to occur, even in sessions without communication (refer to Panels C, D, E, and F). This cooperation appears to have been successful. In the absence of verbal communication, participants appear to make an effort to coordinate the actions of other group members through announced bid and ask prices. In sessions without preferencing, participants' responses suggest that cooperation occurs, but only when communication is permitted (refer to Panels A and B). Notably in two of three sessions without preferencing and without communication, some participants attempt to widen the spread through announced bid and ask prices. Their efforts, however, are unsuccessful.

In sessions with payment for order flow, we also asked participants whether they cooperated, or observed cooperation, in setting rebates and how they would characterize the cooperation. In sessions with (without) communication participants' responses indicate that they explicitly (implicitly) coordinated rebates. In fact, some participants' responses indicate that they sometimes punished those who failed to cooperate even in sessions without verbal communication. According to one respondent (#311, session 15), participants "tried to discipline

each other." Retaliation could take the form of narrow spreads. For example, a spread of $0.00 in period 21 of session 15 resulted in a loss per share equal to the rebate of $0.12 for the individual setting the highest rebate. Such behavior partially explains the narrower spreads observed in sessions with preferencing and payment of order flow as compared to sessions without such payments.

4. Discussion and Concluding Remarks

We use an experimental economics method to examine the effects of verbal communication and order preferencing on quoted bid-ask spreads in multiple dealer settings. We find that in sessions without order preferencing, spreads are wider when verbal communication is allowed. Participants often overtly collude to widen the spread when given the opportunity to communicate verbally. We find that spreads are even wider in sessions with order preferencing. With preferencing, participants do not have incentives to narrow the spread because they do not compete for incoming orders. Hence, wide spreads can be maintained without the necessity of collusive agreements. We also find that participants are willing to compete for order flow using cash payments; however, they appear willing to retaliate against those who are "too competitive." Spreads narrow somewhat when participants are given the opportunity to compete using alternatives to price. Narrow spreads may result because participants attempt to discipline those who quote high order flow payments. In addition, casual observation suggests that competition for order flow using the non-price method spilled over to price competition. The observed waves of competitiveness are deserving of future investigation.

Our data also suggest that in the absence of verbal communication, participants may attempt to coordinate their actions through announced bid and ask prices and order flow payments. Some evidence suggests that coordination occurs in a "loose" sense. Participants quote relatively low bids (high asks) in order to encourage others to decrease (increase) their bid (ask) prices, even when verbal communication is prohibited. And, participants send clear messages regarding high order flow payments by disciplining those who quote them.

The results of this study have important implications concerning the interpretation of earlier studies of dealer behavior. Preferencing and internalization of order flow limit dealers' incentives to narrow bid-ask spreads. Our data suggest that spreads may be wider on NASDAQ because of the structure of the market, not from collusion among dealers.

Future work can examine how the Securities and Exchange Commission's new rules (e.g., public display of limit orders) affect dealer behavior and observed bid-ask spreads. In addition, future investigations may consider how institutional arrangements affect the distribution of income. For example, order flow payments affect not only profit levels, but who gets the profit.

Endnotes

1. In our experimental settings with preferenced order flow, participants act as both brokers for their clients and market makers. Given that preferencing is used by brokers to reward market makers, we assume that it is in each participant's best interest to direct rewards inwardly. Thus, preferencing and internalization are identical. In the remainder of the paper, we use the term preferencing for convenience to describe the situation that arises when a broker/dealer fills a client's order at the inside spread.

2. In the industrial organization literature, the theory of focal points was introduced by Schelling (1960). Overt communication in pricing is dangerous with antitrust legislation. The use of a focal point is a subtle way of coordinating pricing decisions without direct communication.

3. The experimental instructions are available from the authors upon request.

4. Orders may be passed to the participant who offers the best rebate.

5. We use preselected sequences across sessions to maximize comparability. See Cason and Friedman (1996) for discussion of the benefits of using a preselected sequence.

6. Each period is independent so that unfilled orders are withdrawn at the end of a period. An interesting issue for future research is to determine whether observed spreads are affected by (1) the presence of a limit book and (2) whether the information contained in the limit book is open to the public.

7. In our experiment it is possible for one participant to submit the best bid and ask prices in a particular period.

8. Inventory costs can significantly impact dealer behavior. With heterogeneous markets makers, a market maker who fills an order at an inside price he did not quote, will change his inventory in an undesirable fashion (Hansch, Naik, and Viswanathan, 1997). In order to focus on how preferencing impacts behavior, we remove uncertainty about the terminal value of the shares.

9. Participants' responses to the post-experiment questionnaire suggest that they found the experiment interesting and the monetary incentives motivating. Participants responded on a seven-point scale as to how interesting they found the experiment, where 1 = not very interesting and 7 = very interesting. The mean response was 5.61. Participants also responded on a seven-point scale as to how they would characterize the amount of money earned for taking part in the experiment, where 1 = nominal amount and 7 = considerable amount. The mean response was 5.17.

10. Although not formally presented here, we examined whether prices centered around $25, the final share value. We had no reason, a priori, to expect asymmetric deviations between bid and ask prices and the data indicate that bid and ask prices are evenly centered around $25 across sessions.

11. Learning is likely to occur across the initial periods of each session as participants become familiar with the experimental procedures and the behavior of other group members.

12. Goswami, Noe, and Rebello's (1996) experimental evidence suggests that verbal communication among bidders in an auction setting leads to collusive behavior.

13. These results should be interpreted with caution because the observations are not independent over time.

14. Although not reported, the results are similar when the ANOVA is conducted using data from periods 7-24 and 13-24.

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Table 1. Experimental Design

The table presents a summary of the experimental design. We manipulate order preferencing and verbal communication across 18 experimental sessions. In half the sessions verbal communication is permitted. In six sessions (sessions 1-6), market makers compete over order flow and in the remaining 12 (sessions 7-18), orders are preferenced. In six of the sessions with preferenced orders (sessions 13-18), market makers can make payments in an effort to attract order flow.

Sessions	Order Preferencing	Verbal Communication
1-3	No	No
4-6	No	Yes
7-9	Yes	No
10-12	Yes	Yes
13-15	Yes with payment	No
16-18	Yes with payment	Yes

Table 2. Observed Bid-Ask Spreads

The table reports the spread (in dollars) between bid and ask prices each period for all 18 experimental sessions, as well as the average spread for periods 1-24, 7-24, and 13-24 within each session. Panel A contains spreads for sessions without preferencing for both communication settings (without and with). Panel B contains spreads for sessions with preferencing for both communication settings (without and with). Panel C contains spreads for sessions with preferencing and payment for order flow for both communication settings (without and with).

Panel A: Observed Bid-Ask Spreads for Sessions Without Preferencing

Period	Sessions Without Communication			Sessions With Communication		
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
1	$0.875	$0.00	$0.75	$0.875	$1.50	$0.75
2	$1.625	$0.125	$0.625	$0.25	$1.375	$0.375
3	$0.75	$0.00	$0.25	$0.375	$1.125	$0.375
4	$0.75	$0.25	$0.625	$0.50	$3.00	$0.50
5	$0.75	$0.25	$0.50	$0.375	$1.375	$0.50
6	$0.75	$0.375	$0.50	$0.25	$1.00	$0.375
7	$0.50	$0.25	$0.50	$0.375	$0.875	$0.25
8	$0.50	$0.125	$0.25	$0.50	$1.125	$0.25
9	$0.25	$0.25	$0.25	$0.375	$1.00	$0.25
10	$0.125	$0.25	$0.25	$0.50	$0.75	$0.25
11	$0.125	$0.25	$0.25	$0.375	$0.50	$0.25
12	$0.375	$0.25	$0.25	$0.25	$1.25	$0.50
13	$0.25	$0.25	$0.25	$0.375	$1.25	$0.50
14	$0.375	$0.25	$0.25	$0.25	$1.25	$0.50
15	$0.375	$0.25	$0.25	$0.375	$1.25	$0.50
16	$0.25	$0.25	$0.00	$0.375	$1.25	$0.50
17	$0.25	$0.25	$0.125	$0.25	$1.50	$0.50
18	$0.00	$0.25	$0.25	$0.25	$1.50	$0.50
19	$0.125	$0.25	$0.25	$0.375	$1.50	$0.50
20	$0.125	$0.25	$0.125	$0.25	$1.50	$0.50
21	$0.25	$0.25	$0.25	$0.25	$1.50	$0.50
22	$0.25	$0.25	$0.125	$0.25	$1.50	$0.50
23	$0.25	$0.25	$0.125	$0.25	$1.50	$0.50
24	$0.25	$0.25	$0.25	$0.25	$0.50	$0.50
Mean (1-24)	$0.41	$0.22	$0.30	$0.35	$1.29	$0.44
Mean (7-24)	$0.24	$0.23	$0.22	$0.33	$1.19	$0.43
Mean (13-24)	$0.23	$0.25	$0.19	$0.29	$1.33	$0.50

Panel B: Observed Bid-Ask Spreads for Sessions With Preferencing

Period	Sessions Without Communication			Sessions With Communication		
	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
1	$0.50	$1.00	$1.50	$1.25	$1.625	$0.75
2	$0.875	$0.875	$1.75	$1.625	$0.25	$1.25
3	$0.875	$0.25	$1.375	$1.125	$0.25	$2.25
4	$0.75	$0.75	$1.625	$0.75	$0.50	$1.375
5	$0.625	$1.125	$1.75	$0.75	$0.75	$0.75
6	$0.625	$0.50	$1.375	$0.625	$0.625	$0.75
7	$0.625	$0.75	$2.00	$1.625	$0.875	$0.75
8	$0.625	$0.625	$1.625	$0.50	$0.625	$0.50
9	$1.00	$0.75	$1.50	$0.75	$0.50	$0.75
10	$1.00	$1.00	$1.625	$0.50	$0.875	$1.875
11	$0.75	$0.50	$1.50	$1.00	$1.00	$1.25
12	$0.625	$0.75	$1.375	$1.00	$0.625	$1.125
13	$1.00	$0.75	$1.625	$0.625	$1.375	$0.75
14	$1.00	$1.00	$1.50	$0.50	$0.875	$0.75
15	$1.00	$1.125	$1.50	$1.125	$0.75	$1.25
16	$1.125	$1.00	$1.375	$1.00	$1.00	$1.50
17	$1.125	$1.00	$1.375	$1.125	$1.125	$1.25
18	$1.00	$0.875	$1.375	$1.125	$1.125	$1.25
19	$1.25	$0.875	$1.375	$1.00	$1.00	$1.50
20	$1.25	$0.50	$1.25	$0.875	$1.00	$0.875
21	$1.25	$0.75	$1.25	$0.75	$1.125	$1.50
22	$1.25	$1.00	$1.00	$0.625	$1.00	$1.375
23	$1.25	$1.00	$1.375	$0.875	$0.875	$1.875
24	$1.25	$0.625	$1.125	$0.875	$1.00	$1.625
Mean (1-24)	$0.94	$0.81	$1.46	$0.92	$0.86	$1.20
Mean (7-24)	$1.02	$0.83	$1.43	$0.88	$0.93	$1.21
Mean (13-24)	$1.15	$0.88	$1.34	$0.88	$1.02	$1.29

Panel C: Observed Bid-Ask Spreads for Sessions With Preferencing and Payment for Order Flow

Period	Sessions Without Communication			Sessions With Communication		
	Session 13	Session 14	Session 15	Session 16	Session 17	Session 18
1	$0.75	$0.75	$0.625	$0.75	$1.50	$1.125
2	$0.625	$0.625	$0.875	$1.00	$1.50	$0.875
3	$0.875	$1.125	$0.875	$1.125	$1.50	$0.875
4	$0.75	$1.125	$0.875	$1.00	$0.75	$0.75
5	$0.75	$1.125	$0.875	$0.625	$1.00	$1.00
6	$0.625	$1.125	$0.75	$1.00	$0.75	$1.00
7	$0.625	$0.75	$0.50	$1.00	$0.875	$1.00
8	$0.75	$0.75	$0.50	$0.375	$1.00	$1.00
9	$0.625	$0.75	$0.50	$1.00	$0.875	$0.75
10	$0.625	$0.75	$0.625	$1.00	$0.625	$0.75
11	$0.625	$0.75	$0.625	$1.25	$0.75	$0.75
12	$0.75	$0.875	$0.375	$1.00	$0.50	$0.75
13	$0.75	$0.875	$0.625	$1.125	$0.75	$0.75
14	$0.00	$1.125	$0.625	$1.00	$0.75	$0.75
15	$0.25	$0.875	$0.625	$1.00	$0.75	$0.75
16	$0.625	$0.875	$0.25	$1.25	$0.625	$0.75
17	$0.625	$1.00	$0.00	$1.25	$0.75	$0.75
18	$0.00	$1.00	$0.50	$0.75	$0.75	$0.75
19	$0.75	$1.00	$0.375	$0.75	$0.75	$0.75
20	$0.75	$0.875	$0.25	$0.625	$0.75	$0.75
21	$0.75	$0.875	$0.00	$0.75	$0.75	$0.75
22	$0.625	$0.875	$0.375	$0.75	$0.75	$0.75
23	$0.625	$0.875	$0.375	$0.625	$0.75	$0.75
24	$0.75	$0.875	$0.50	$0.75	$0.75	$0.75
Mean (1-24)	$0.62	$0.90	$0.52	$0.91	$0.85	$0.82
Mean (7-24)	$0.58	$0.875	$0.42	$0.90	$0.75	$0.78
Mean (13-24)	$0.54	$0.93	$0.38	$0.88	$0.74	$0.75

Table 3. ANOVA Results of the Effects of Communication and Preferencing on the Observed Bid-Ask Spread

The table provides evidence concerning the effects of communication (without and with), preferencing (without, with, and with along with payment for order flow), and their interaction on observed bid-ask spreads. The table reports the results of analysis of variance using data from all 18 experimental sessions. Included in the table are the degrees of freedom (df), sum of squares for each treatment and for the total error, an F-statistic which tests for differences among the treatments, and the p-value for each F-statistic.

Variable	df	Sum of Squares	F-statistic	p-value
Communication	1	2.75	23.15	0.000
Preferencing	2	20.28	85.46	0.000
Interaction	2	3.84	16.16	0.000
Error	426	50.56		

Table 4. ANOVA Results of the Simple Effect of Communication on the Observed Bid-Ask Spread

The table provides evidence concerning the relationship between communication (without and with) and the bid-ask spread. Panel A of the table reports the results of an analysis of variance using data from sessions 1-6. Panel B reports the results of an analysis of variance using data from sessions 7-12 and Panel C using data from sessions 13-18. Included in each panel of the table are the degrees of freedom (df), sum of squares for the treatment and for the total error, an F-statistic which tests for differences among the treatment, and the p-value for each F-statistic.

Panel A: Sessions Without Preferencing

Variable	df	Sum of Squares	F-statistic	p-value
Communication	1	5.252	32.429	0.000
Error	142	22.997		

Panel B: Sessions With Preferencing

Variable	df	Sum of Squares	F-statistic	p-value
Communication	1	0.224	1.562	0.213
Error	142	20.332		

Panel C: Sessions With Preferencing and Payment for Order Flow

Variable	df	Sum of Squares	F-statistic	p-value
Communication	1	1.107	21.745	0.000
Error	142	7.228		

Table 5. ANOVA Results of the Simple Effect of Preferencing on the Observed Bid-Ask Spread

The table provides evidence concerning the relationship between preferencing (without, with, and with along with payment for order flow) and the bid-ask spread. Panel A (B) of the table reports the results of an analysis of variance using data from the nine sessions in which communication is (not) allowed. Included in each panel of the table are the degrees of freedom (df), sum of squares for the treatment and for the total error, an F-statistic which tests for differences among the treatment, and the p-value for each F-statistic.

Panel A: Sessions With Communication

Variable	df	Sum of Squares	F-statistic	p-value
Preferencing	2	3.249	10.825	0.000
Error	213	31.968		

Panel B: Sessions Without Communication

Variable	df	Sum of Squares	F-statistic	p-value
Preferencing	1	20.870	119.564	0.000
Error	142	18.589		

Table 6. A Sample of Responses Characterizing the Process Used to Determine Bid and Ask Prices

Panels A-F contain a sample of participants' responses by experimental condition to the following open-ended question: how would you characterize the process by which you decided on your quoted bid and ask prices? We report one response from each experimental session, and participants' experimental codes are shown preceding their responses. Reported responses are representative of those of other group members in the same session.

Panel A: Sessions Without Preferencing, Without Communication

Session 1, #234: I wanted to make money, but I also wanted to ensure that the other participants did not block me out of the market - i.e., I tried to stay close to $25 but never at $25 because there was no money to be made.

Session 2, #244: As soon as I realized that someone was always going to undercut my prices, I decided to stay at the most competitive prices where you could still make a profit by getting as many deals as possible.

Session 3, #254: Tried to get in on the action since everyone else was just 1/8 off the reference point.

Panel B: Sessions Without Preferencing, With Communication

Session 4, #201: Reacted to what other members quoted previously.

Session 5, #212: For the first 10 periods I tried to have the lowest ask price of the competitors while still profiting - very competitive during these rounds. After period 11 the group conferred once we realized we could maximize our gain by setting our range constant.

Session 6, #221: In the beginning, I considered the prices chosen by others and guessed at what their new prices would be. Nearing the end, though, we colluded.

Panel C: Sessions With Preferencing, Without Communication

Session 7, #134: I looked to set the probability of bids and asks being above or below certain values. I determined the 50% level and tried to keep my bid and ask at this level.

Session 8, #141: I wanted to stay on the outer edge of my estimates of what they would bid. I felt that if I could influence the bidding it would be to my benefit, i.e., to earn more money.

Session 9, #153: What others bid and ask and what amounts my clients usually wanted to pay to buy or sell.

Panel D: Sessions With Preferencing, With Communication

Session 10, #103: I was guaranteed a market in the final period for selling or buying the needed shares at $25 so I was not worried about keeping share balance at 200. The idea was to get as many orders but this was very random. All in all I noticed the best combination for the spread and probability of having orders was at or around 24 4/8 and 25 4/8. Also, I noticed the other market makers were around those prices so there was no need for me to make the market.

Session 11, #112: Cooperate with others, look at last quotes, looked at distribution sheets, decided near end that I desired at least 4/8 below max (bid) and 4/8 above min (ask) to get decent profit but still obtain many of the offers.

Session 12, #123: I considered what my group members were bidding and asking and the probability of the prices given. My bid and asks were lower and higher than most people because I did not want to squeeze the margins.

Panel E: Session With Preferencing and Payment for Order Flow, Without Communication

Session 13, #314: Fair profit considering the going rebate and how often orders are lost.

Session 14, #321: I ballparked top 1/3 of distributions to get 24 3/8 and 25 5/8.

Session 15, #334: I wanted to guarantee a minimum expected profit, so I didn t set the bid price very high, or the ask price very low. Also the bid and ask prices would get me around 50% of the offers.

Panel F: Sessions With Preferencing and Payment for Order Flow, With Communication

Session 16, #343: At the beginning of the experiment I just wanted some points below 25 for bids and some points above for ask price. On subsequent periods after setting a very high rebate and a very narrow margin, I decided to keep low rebates and set my prices according to past periods.

Session 17, #353: Observed bidding from previous periods … it appeared that an informal agreement was made to set minimum price difference beyond which none of the other market makers would move.

Session 18, #361: Collusion with the other members.

Table 7. A Sample of Responses Characterizing the Nature of Cooperation Observed During the Experiment

Panels A, B, C, and D contain a sample of participants' responses by experimental condition to the following open-ended question: how would you characterize cooperation observed during the experiment? We report one response from each experimental session, and participants' experimental codes are shown preceding their responses. Reported responses are representative of those of other group members in the same session.

Panel A: Sessions Without Preferencing, Without Communication

Session 1, #231: Initially all members bid and asks outside of the $25 range. However, once members started crowding the 25 dollar figure, it was difficult to make $ therefore I attempted with others to move the price up and down to allow us to make more profit. But there were members who did not wish to move, thereby creating 24 rounds of bid 24 7/8 and ask 25 1/8. Overall, frustrating.

Session 2, #243: I tried to lead everybody verbally by asking specific questions and the way in which I announced my bid and ask. I felt that nobody else made an attempt at this, maybe one other guy. But it just ended up going down to the least one every time.

Session 3, #251: Without talking, hoping cooperation would occur so everyone can maximize earnings. However, competitive nature of business students is bad enough to want to beat others, even at the cost of self-sacrifice.

Panel B: Sessions Without Preferencing, With Communication

Session 4, #203: Don't think they wanted to cooperate, a few attempts seem to have failed.

Session 5, #213: We set the bid price of 24 2/8 and the ask of 25 6/8; tried to achieve a range that would generate a relatively high amount of cash, while at the same time achieving a range with approximately 50% probability of filling the market orders.

Session 6, #224: It became evident early on (actually about half way through) that cooperating would maximize the earnings of the group. We verbally agreed, and no one cheated.

Panel C: Sessions With Preferencing, Without Communication

Session 7, #133: No, I don't think it was cooperation, but once a pattern of holding the same bid started, the others started coming closer to my bid, which was the lowest bid and highest ask price.

Session 8, #142: I feel some of the other group members began to use the same strategy.

Session 9, #154: Staying within average bid and ask by +/- 3/8.

Panel D: Sessions With Preferencing, With Communication

Session 10, #102: We tried to increase the spread in order to make money in larger amts for each transaction, it did not, however, work.

Session 11, #113: We determined a limit of what an appropriate bid and ask would be and then set levels in that range.

Session 12, #121: Verbal communication of prices. Not everyone stuck to price agreed upon but most of the time they stayed reasonably close.

Panel E: Sessions With Preferencing and Payment for Order Flow, Without Communication

Session 13, #313: It was a tacit agreement that prices were likely to fall within a set range.

Session 14, #321: No cooperation.

Session 15, #332: More competition than cooperation.

Panel F: Sessions With Preferencing and Payment for Order Flow, With Communication

Session 16, #344: Implicit. We got into a routine of setting bid/ask around the range of 24 3/8 - 24 6/8 and 25 3/8 - 25 5/8. We never got out of that routine.

Session 17, #353: In setting bid/ask prices, agreement was formalized early but abandoned to concentrate on rebate portion since we drove ourselves to near profits 0 at one point in the experiment.

Session 18, #362: Collusion seemed to work the best for us over time.