# Addendum to "Herd Behavior in a Laboratory Financial Market:" the Bid-Ask Treatment

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In this note, we discuss the behavior of traders in an additional treatment (which we label "bid-ask spread" treatment) in which two participants acting as market makers set two prices, an ask price and a bid price. The note is organized as follows. Section $I$ describes the experiment. Section $II$ discusses the results. An Appendix contains the instructions of the experiment.

## I. The Experiment

The experiment was run in the ELSE Center at University College London. We ran four sessions. In each session, 12 subjects acted as traders. They could trade, in sequence, with two subjects acting as market makers. Two more subjects, the subject administrators, helped us in running the experiment. Therefore, for the experiment, we used a total of 64 subjects. In each session, we repeated the experiment for 10 rounds.

The procedures for the subjects acting as traders are identical to those described in the main paper. Here we only describe the procedures for the mechanism of price formation.

In this experiment, the price was endogenously set by two subjects. These two experimental market makers chose a bid and an ask price for each trading

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period and updated them on the basis of the order flow. They chose their first bid and ask prices before any subject had traded. They independently wrote them on a worksheet without observing each other. After they had both made their choices, a subject administrator recorded the two bid and the two ask prices on the blackboard. Then, he called the first subject to trade. After observing the prices and the subject's decision (also recorded on the blackboard), the market makers chose their new bid and ask prices. One of the subject administrators wrote the revised prices on the board and called the next subject. The process continued until all 12 subjects had made their choice. The subjects could trade at the better of the prices set by the two market makers, i.e., buy at the lower ask and sell at the higher bid.

For each trading period, we asked the two market makers not only to choose the bid and ask prices but to provide us with an estimate of the asset value.[1] We told market makers to set the bid and ask prices around this estimate.[2] In designing this procedure for the market makers, we followed previous work in the experimental market microstructure literature (see, e.g., Robert Bloomfield and Maureen O'Hara, 1998, 1999, 2000, who use this setting to investigate various properties of a sequential trade mechanism).

In a setup where all traders are informed, informational asymmetries would cause the market to collapse. In particular, rational market makers would set a bid and ask spread so wide that informed traders would not gain (in expected value) from trading. To avoid this, we needed some noise traders. At the same time, however, we wanted to keep the procedures for traders identical to those of the other treatments and we wanted to keep the number of informed traders constant across treatments.

In order to achieve both objectives, we designed the market makers' payoff in the following way. In each trading period, the market makers' payoff depended with probability one half on the actual trade made by the experimental subject and with probability one half on a random decision by a computer program. The computer bought with probability $\frac{1}{2}$ and sold with probability $\frac{1}{2}$. This mechanism assured that, in each round, market makers would observe an informative action coming from a subject (as in the endogenous pricing treatment). At the same time, however, trading did not

[1] Given that the asset was worth either 0 or 100 lire, each price setter's estimate was his own belief on the chance that the asset was worth 100. By eliciting market makers' estimates, we have an easy way of comparing their expected values with the prices set in the endogenous pricing treatment.

[2] The expectations of the two market makers were not recorded on the blackboard.

necessarily mean making expected losses. Market makers would lose money (in expected value) when trading with informed subjects, but would make money (in expected value) when trading with the computer.[3] Bertrand competition between market makers assures that they should set a bid ask spread that did not keep informed traders out of the market (since in this case, market makers would be making positive profits in expected value).

It is easy to see that the payoffs of the market makers resulting from this mechanism are equivalent to those of the theoretical model of Lawrence Glosten and Paul Milgrom (1985). Theoretically, the two market makers should always set the bid price equal to the expected value of the asset conditional on the history of trades and on a sell order (coming from an informed trader or a noise trader). Similarly, they should set the ask price equal to the expected value of the asset conditional on the history of trades and on a buy order.

We provided the market makers with a fixed amount of 100 lire for each trading period. At the end of the experiment, the total amount of lire earned by the market makers during the experiment was divided by 12 and then exchanged in currency as for the traders. We divided the total amount by 12 as market makers received the fixed endowment 12 times as often as traders. This guarantees that market makers and traders could earn a similar amount of money for their participation in the experiment.[4]

We also provided market makers an incentive to estimate the value of the asset accurately by paying them a bonus for each estimate. This bonus was equal to lire $10 - \dfrac{(v - estimate)^2}{1000}$. This scoring function, widely used in the literature to elicit beliefs (see, e.g., Yaw Nyarko and Andrew Schotter, 2002), implies a truthful revelation of beliefs if agents are risk neutral.[5]

[3] Payoffs were calculated assuming that the computer was always trading at the better price (exactly as the subjects). For example, consider the case in which a subject decided to buy and the payoffs depended on the computer's decision, which was a sell. Assume that the first market maker posted the lower ask and the second market maker posted the higher bid. In this case, although the subject had bought, the first market maker obtained the payoff of a no trade and the second market maker the payoff coming from a sell order.

[4] Since computing the payoffs period by period would have taken too long, the market makers received a printout with all their actions and payoffs at the end of each round.

[5] As is true of all scoring functions, the payoff resulting from declaring a different belief guarantees a higher minimum payment. In our case, declaring an estimate of 50 would guarantee the largest minimum payment. Given our payoff structure, however, plausible levels of risk aversion would make the optimal strategy for a risk averse agent close to that

Finally, given that market makers' task was harder than that of the traders, we trained them before the experiment.[6] Notice that only the market makers were trained. This assures that the behavior of subjects acting as traders is comparable to that observed in the other treatments.

At the end of the experiment we paid subjects in private. The experiment lasted on average 2.5 hours.

# II. Results

As in the treatments of the main paper, the results reported for this experiment refer to the last seven rounds of each session. Given that in each round there were 12 trading decisions, our results refer to a total of 336 trading decisions.

Let us start by discussing how market makers estimated the asset value. On average, in the entire experiment, market makers updated the estimates of 11.4 lire after a buy, −11.2 lire after a sell and of 0.4 lire after a no trade. Table 4 summarizes the market makers' updating after a trading decision for different levels of the trade imbalance (in absolute value). The table contrasts these updating rules with the Bayesian ones that we used in the flexible price treatment. When the trade imbalance was 0, after a buy or a sell order market makers updated their estimates less than a Bayesian subject would do assuming that traders were perfectly rational. In other words, market makers did not give as much weight to just one buy or sell order and waited for more orders to come in order to modify the price in a certain direction. In contrast, when the trade imbalance increased (in absolute value) to 1 or 2 or 3 they updated the estimates slightly more than we did following the theoretical model. For higher trade imbalances, their updating is similar to ours. It's also important to note that after a no trade, they barely moved the estimates. Moreover, note that the maker makers updated the asset value's

of a risk neutral agent. Moreover, the fact that the estimate payment was small compared to the trading losses and gains, makes it unlikely that subjects would use the estimate payoff to hedge the potential loss stemming from the trade payoff. In fact, there is no evidence of such a strategy in the data.

[6] In the training sessions, participants received the same instructions as in the experiment. They were told that they were participating in a training session aimed at making the rules of the experiment clear to them. In the training session, the role of traders was played by a computer software, which simulated a sequence of trading orders. At the end of each round, each market maker was informed of the realized value of the asset and could compute his payoff. The training sessions lasted on average 2.5 hours.

estimates in a remarkably similar way to how they updated the prices in the endogenous pricing treatment.

Table 6 shows how the bid-ask spread evolved over trading rounds. While one would expect the spread to decrease over time, in our experiment it remained almost constant. We should note, however, that this result is mainly due to the behavior of the market makers in one of the sessions of the experiment. These two market makers, whose behavior represents an outlier in the experiment, actually had a tendency to increase the bid-ask spread over time. Without taking this session into account, the bid-ask spread is decreasing, as one would expect (it goes from 15 in period 1 to an average of 8 for the periods from 2 to 11, to a value of 5 in period 12). While the behavior of these two markets makers affected the results on the bid-ask spread, it did not have a relevant impact on our results relative to trading behavior, as we will show below.

When prices are set by experimental subjects, it is not necessarily the case that the optimal decision for a rational trader is to follow the signal.[7] First, if the bid and ask spread is "too large," then no trading becomes a rational decision. Second, a rational agent may find it optimal to trade against the signal simply because the prices are set too high or too low.

Given the bid and ask prices set by the market makers and the realizations of the signals, following private information was the optimal decision 67 percent of the time. No trade was optimal 32 percent of the time, while trading against the signal was optimal only 1 percent of the time. This shows that market makers had a tendency to set a bid-ask spread larger than what theoretically expected.

Let us now move to the discussion of traders' behavior. Table 3 shows the proportion of rational and irrational decisions given the prices set by the market makers. The average level of rationality in the treatment is 58 percent, very similar to that observed in the other treatments with flexible prices. Irrational no trading decisions accounted for 19 percent of total decisions. The remaining 23 percent of decisions were buying and selling against private information.

Let us now consider herd behavior. We observed 85 periods in which the trade imbalance was at least 2 (or at most $-2$) and the subject received a negative (positive) signal. In these periods subjects decided to go against

[7] In order to classify a decision as rational or irrational, we make the same assumptions about subjects' beliefs as in the main paper.

their private information in 19 percent of cases. In 49 percent of cases they decided not to trade and in 32 percent they followed their signal even if it was at odds with the history of trades. These results are similar to those of the other treatments with flexible price (see Table 1).[8] Note that only a very modest percentage (6 percent) of the decisions to herd can be considered rational given the prices set by the market makers.

As for contrarianism, there were 116 periods in which subjects could have potentially acted as contrarians, i.e., the trade imbalance was at least 2 (or at most $-2$) and the trader received a signal in accordance with it. Subjects behaved as contrarians in 10 percent of cases, whereas in 47 percent they decided not to trade and in 43 percent they followed their private information. The percentage of contrarian behavior is identical to that of the no-history treatment, but smaller than that of the endogenous price treatment and of the flexible price treatment.[9] At the same time, however, the proportion of no trades in these periods is twice as much as that observed in the other treatments with flexible price. It is also interesting to note that none of these decisions to act as contrarian can be considered rational, given the prices at which they were made.[10]

In conclusion, the presence of a bid and ask spread did not modify traders' propensity to herd or the overall level of rationality in the experiment. It reduced contrarian behavior and increased the proportion of no trades. Since

[8] Mann-Whitney tests for the hypothesis that the proportion of herd-like decisions was the same under this treatment and the flexible price, no-history or endogenous price treatments cannot be rejected at the 5 percent significance level ($p - values$ = 0.66, 0.47, 0.77).

[9] A Mann-Whitney test for the hypothesis that the proportion of contrarianism was the same under this treatment and the no-history treatment cannot be rejected at the 5 percent significance level (p-value=0.88). However, we can reject the hypothesis that this proportion is the same under this treatment and the flexible price or the endogenous pricing treatments.

[10] As we said, the market makers in one session set the bid and ask price in a different way than the average behavior. While this did affect the average bid-ask spread, it had a limited impact on traders' behavior. Indeed, if we restrict our analysis to the other three sessions, the figures for herding and contrarian behavior are very similar to those presented above. For contrarian behavior the figures are almost identical: in situations of potential contrarian behavior, subjects behaved as contrarians in 11 percent of cases, did not trade in 43 percent, and followed private information in the remaining 46 percent. As for herd behavior, subjects ignored the signal and herded 12 percent of cases, did not trade 47 percent, and followed private information 41 percent. Finally, the average rationality in the three sessions was 57 percent.

in actual financial markets the size of the bid-ask spread varies significantly, the results of our treatment suggest that we may find more contrarianism in liquid markets, i.e., markets where the bid-ask spread is lower. In most financial markets, however, the average size of the bid-ask spread is much smaller than in our experiment. Therefore, one should be cautious in evaluating the quantitative importance of the presence of a bid-ask spread in reducing contrarianism and increasing no trading.

Finally, let us discuss price convergence. Figure 1 shows the difference between the theoretical and actual estimates given by market makers at time 13. The theoretical estimates are computed assuming that traders always follow their signal and, therefore, that all signals are public. Similarly to the flexible price and endogenous pricing treatments, 57 percent of the time the distance was lower than 10. However, 4 times (out of 28) the difference between the actual price and the theoretical one was close to 100 (e.g., the actual price was close to 100 when the theoretical price was close to 0). Moreover, 21 percent of the time the distance was greater than 30, a proportion identical to that observed in the endogenous pricing treatment. As a result, the average distance between the theoretical and the actual last estimates is 16, very close to what observed in the endogenous pricing treatment, but slightly higher than what observed in the flexible price treatment.

# References


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# Appendix: Instructions

## Introduction

Welcome to our experiment!

Please, read these instructions carefully. Take all the time you want to go through them. Make sure you understand everything. If you have a question, please, do not hesitate to raise your hand. We will be happy to come to you and answer it privately.

You are about to engage in an experiment in market decision making. Various research institutions have provided funds for this experiment. If you make appropriate decisions, and have some luck, you may earn a good monetary payment. You will be paid immediately after the end of the experiment.

## The experiment

The experiment consists of a series of 10 rounds. In each round you will have the opportunity to trade a good.

*The good*

The good you are going to trade will ultimately be worth either 0 or 100 units of an experimental currency called "lire." These lire will be converted into pounds at the end of the experiment at the rate of £1 = 100 lire. Whether the good will be worth 0 or 100 lire will be determined at the beginning of each round by flipping a coin: if the coin lands heads the value will be 0 lire and if the coin lands tails it will be worth 100 lire. Hence, there is half a chance of the good having a value of 0 or 100. Clearly, given that we toss the coin again at the beginning of each round, the value in a round does not depend on the value in the previous rounds.

*The trading process*

In total there are 14 participants in this experiment. Twelve participants will be "traders," and the remaining two "price setters." If you are a trader, you will buy, sell or no trade one unit of the good with the price setters. If you are a price setter, you will choose the prices at which to trade with the traders. Trading happens according to the following mechanism. First the price setters choose the prices. Then the trader announces whether to buy, sell or not trade at those prices. The price setters must trade with the trader at the prices they had chosen.

Trading will occur sequentially. In each round, the twelve traders will make their decisions one after the other. Before starting the experiment, we will randomly assign a number from 1 to 12 to the twelve traders. *Traders: please, write the number assigned to you on your worksheet, after your name.*

*Procedures for each round*

As we said, there will be 10 rounds in this experiment. Let us examine the procedures for each round.

**First**, out of the room, we will flip a coin. The outcome of this coin flip will determine the value of the good for that round: if the coin lands head the value will be 0 lire and if the coin lands tail it will be 100 lire. Of course, we will not tell you the outcome of the coin flip.

**Second,** the prices at which the trader will be able to trade are posted on the blackboard.

**Third**, we will start calling the twelve traders, using their identification numbers. The order in which we call traders is randomly decided by using a deck of 12 cards. All traders will be given the opportunity to trade. Therefore, in each round there will be 12 decisions, one for each trader. When a trader is called to trade, he will go out of the room and draw a chip from one of two boxes. While both boxes contain only two types of chips, white chips and blue chips, the proportion of the two types of chips in each box is different (you can verify this at the beginning of the experiment). One box contains 70 blue and 30 white chips and the other box 30 blue and 70 white chips. If the value of the good is 0 (as determined by the coin flip), we will ask the trader to draw the chip from the box that contains 70 blue and 30 white chips. If the value is 100, we will ask to draw the chip from the box that contains 70 white and 30 blue chips. To recap:

- If the value is 100, then there are more WHITE chips in the box.

- If the value is 0, then there are more BLUE chips in the box.

Therefore, the chip gives some information about the value of the good. After the participant has drawn the chip and looked at its colour, he will put it back into the box, so that the number of chips in the box never changes. *The colour of this chip is private information – it cannot be shared with any other subject.*

**Fourth,** when the trader goes back to the classroom he announces his trade, i.e., whether he buys, sells or not trade at given prices**.** All traders can observe the choices that have been made by the previous subjects and the prices at which they had traded (we will write them on the blackboard). Therefore, when a trader announces his trade (sell, buy or no trade), he knows what the people who had traded before had decided to do. *The trader will record the price at which he trades and his decision (check one among Buy, NT=No trade, and Sell) in columns 2 and 3 of his worksheet in the row referring to Round 1.*

If you happen to be a trader, you have already learnt what you will have to do. But at what prices will you be able to trade? As we said, this is decided by the price setters.

Before each trading decision, each price setter will have to decide what his estimate of the asset value is. Each price setter's estimate is his own belief on the chance that the asset is worth 100. E.g., if a price setter is convinced that there is 80 percent chance that the asset is worth 100, his estimate will be 80. Moreover, before each trading decision, the two price setters will decide two prices, one price (the buy-price) is the price at which traders will be allowed to buy; the second price (the sell-price) is the price at which the traders will be allowed to sell. The price setters are obliged to set the sell-price equal or lower than the their estimate and the buy-price equal or higher than their estimate. Moreover, these two prices must be between 0 and 100 (included).

When both price setters have made their mind, *they will write the estimate, the buy-price and the-sell price on their worksheet.* Price setters cannot communicate among themselves and have to choose their prices independently. We will report these prices on the blackboard (so that everyone can see them) only after both price setters have written down their prices in the worksheet. *The trader will always trade at the most favourable of the two prices.* For instance, imagine that a price setter chooses a buy-price of 80 and the other a buy-price of 76. Suppose that the trader decides to buy. Then he can do it at the lower buy-price of 76. Suppose now that the two price setters choose a sell-price of 60 and of 65. If the trader wants to sell, he can do it at the higher sell-price of 65.

Price setters will choose the first expectation, buy-price and sell-price before any trader has made a decision. Then, after the first decision has been made, they will be free to revise the expectations and the prices. Similarly, after each subsequent trader's decision, they can change the expectations and prices again.

At the end of the round, after all subjects have made their buy, sell, or no-trade decisions, we will inform you of the value of the good in that round and of your payoff. *Traders: You will write this value and your payoff in columns 4 and 5 of the row referring to Round 1.*

**The traders' payoff**

If you are a trader, your payoff when you trade will be determined as follows. You will first be given 100 lire just for trading. In addition to that, you will be paid an amount that varies depending on your trading decision, the price at which you trade and the value of the good. In particular,

- *If you decide to buy at the price p you will get*

$$100 + Value - p.$$

- *If you decide to sell at the price p you will get*

$$100 + p - Value.$$

- *If you decide not to trade you will earn* 100 *lire.*

Why these payoffs? If you buy, you get the value of the good and you have to pay its price. If you sell, you have to borrow the good in order to sell it. You get the price at which you sell and have to repay the value of the good.

Therefore, when you buy, you will gain lire if the value of the good is higher than the price and lose them if it is lower. When you sell, you will gain lire if the price is higher than the value and lose them if it is lower. Always remember that the value of the good can be either 0 or 100. Notice also that you will never have a negative payoff, given that we give you 100 lire for trading. However, if you make the wrong decision, you will lose in part these 100 lire.

**Example**

Suppose that, when it is your turn to trade, the two posted sell-prices are 67 and 70 and the two posted buy-prices are 74 and 76. Therefore, you can buy the good at the better of the two posted buy-prices (i.e., the lower one, 74) and you can sell the good at the better of the two posted sell-prices (i.e., the higher one, 70). There are two possibilities: either the good is worth 0 or it is worth 100. If you decide to buy and the good is worth 0, then you get $100+0-74 = 26$. In this case you lose your money, because you bought for a price of 74 something that is worth 0. If you buy and the good is worth 100, then you get $100+100-74 = 126$. In this case, you earn more money because you bought for only 74 lire a good that is worth 100 lire. If you decide to sell and the good is worth 0, then you get $100 + 70 - 0 = 170$. In this case you earn more money, because you sold for a price of 70 something that is worth 0. If you sell and the good is worth 100, then you get $100 + 70 - 100 = 70$. In this case, you lose your money because you sold for 70 lire a good that is worth 100 lire. Finally, if you decide not to trade, you will simply keep your initial 100 lire.

**The price setters' payoff**

If you are a price setter, your payoff is made of two components. The first component, the trading component, depends on how much you gain by trading. The second component, the estimate component, on how well you choose your estimate of the asset value. We first describe the trading component and than the estimate component of a price setter's payoff.

**The trading component of a price setter payoff.**

The trading component is determined similarly to the traders' payoff. However, for each trade, only 50 percent of the time your payoff will depend on what the trader actually decides to do. The other 50 percent of times your payoff will be computed **as if** you were trading with a computer who chooses whether to buy or sell randomly. In particular, the computer buys 50 percent of the time and sells 50 percent of the time, no matter what the value of the good is, the present prices are, or what the trader decides to do.

Why do we do that? We want to compensate you for the fact that you are trading with people who saw the chip colour before trading, while you did not. For instance, let's say that both you and the other price setter choose a very high price, such that, at that price, it is unlikely that any trader would ever buy. Nevertheless, 50 percent of the time your payoff will be computed as if you were trading with a computer and half of these time, the computer will buy **even at** that high price. Notice, however, that also for the computer holds the same rule applied to the traders: a buy occurs always at the lower price and a sell at the higher one.

After the trader has announced his decision, we will inform you of whether your payoff is going to be determined by the trader's decision or by the computer's random decision. Note that in both instances the trade will happen at the lower buy price and at the higher sell price. Therefore, the trading component of your payoff will be as following:

- *If you do not trade (because the other price setter trades or because the trader decides not to trade), you will get*

$$100.$$

- *If the trader (or the computer) decides to buy from you at the buy price $b$, this is equivalent to a sell for you. Therefore, you will get*

$$100 + (b - Value).$$

- *If the trader decides to sell from you at the sell price $s$, this is equivalent to a buy for you. Therefore, your trading payoff will be:*

$$100 + (Value - s).$$

As we said, trade will occur at the price more favourable to the trader (or to the computer). Therefore, for each occurring trade, one price setter will receive the payoff deriving from that trade; and the other the payoff deriving from the no trade. In the case in which the price setters choose exactly the same price, only one price setter will trade at that price. The computer will choose this price setter randomly.

**The estimate component of a price setter payoff.**

As we said above, before each trade you decide your estimate of the asset value. For each estimate decision, you receive a payoff depending on how correct your estimate is. In particular, if you guess the asset value correctly you will get 10 lire. However, if you make a mistake, we will subtract from these 10 lire the square value of your mistake (i.e., the difference between your guess and the asset value) divided by 1000. This means that the estimate component of your payoff will be

$$10 - \frac{mistake^2}{1000}$$

We will approximate your payoff to the nearest lira.

**Example.** If your estimate of the asset value is 75 and the asset value turns out to be 100, you made a mistake of 25. Therefore, your payoff deriving from the estimate would be $10 - \frac{25^2}{1000} = 9$. If your estimate is 75 and the asset value turns out to be 0, you made a mistake of 75. Therefore, your payoff deriving from the estimate would be $10 - \frac{75^2}{1000} = 4$.

**After the twelfth subject has made his/her decision, the first round is over.** We will then proceed to the other rounds, where the same procedures of the first round will be repeated. At the beginning of the new round, the value of the good will be determined by a new coin flip. Then you can trade. *Of course, you will proceed to the other rows of your worksheet and record prices, trade decisions and payoffs there.*

**How your final payment is determined.** For the simple fact that you show in time for the experiment you earn £7. The rest of the payment depends on how you perform.

If you are a trader, first, we will sum up your payoffs in lire for all the 10 rounds. We will then convert these lire into pounds at the rate of # *pounds* $= \frac{\#\ lire}{65}$. For instance, if after 10 rounds you made 1000 lire you will receive $\frac{1000.0}{65}$ pounds, that is, £15.4. Your final payment will be equal to this amount plus the £7.

If you are a price setter, first, we will sum up, for each trade, your trading payoffs and your estimate payoffs. Then we will sum your payoffs for all the 10 rounds and divide this amount by 12. Why do we divide by 12? To take into account that the price setters receive a payoff 12 times as often as the traders. We will then convert these lire into pounds at the rate of $\#\ pounds = \frac{\#\ lire}{65}$. For instance, if after 10 rounds you made $12000/12 = 1000$ lire you will receive $\frac{1000}{65}$ pounds, that is, £15.4. Your final payment will be equal to this amount plus the £7.

The payoffs are computed in such a way that you can earn a similar amount of money (if you perform in a similar way) independently of whether you are a trader or a price setter.