How Communication Improves Efficiency in Bargaining Games

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Received December 22, 1998

We study a double auction with two-sided private information and preplay communication, for which Myerson and Satterthwaite (1983, *J. Econ. Theory* 28, 265–281) showed that all equilibria are inefficient and the Chatterjee–Samuelson linear equilibrium is most efficient. Like several others, we find that players use communication to surpass equilibrium levels of efficiency, especially when the communication is face-to-face. Our main contribution is an analysis of how communication helps the parties achieve such high levels of efficiency. We find that when preplay communication is allowed, efficiency above equilibrium levels is a

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1 We are indebted to the Center for Advanced Study in the Behavioral Sciences for the opportunities it afforded us to spend time together and for fellowships to Gibbons and Thompson funded in part by National Science Foundation (NSF) grant SBR-90221192. Thompson also gratefully acknowledges NSF grants SES-9210298 and PYI-9157447. We thank the Harvard Business School for funding the experiment presented here, and seminar participants at Cal Tech, Cornell, Harvard, Northwestern, Pittsburgh, and Stanford for helpful comments. The reverse-alphabetical authorship order of this paper complements the alphabetical authorship order of our other papers.
result of what we call “dyadic” strategies that allow the parties to coordinate on a single price that reflects both parties’ valuations. *Journal of Economic Literature*

Classification Numbers: C78, D82. © 2002 Elsevier Science

*Key Words:* private information games; preplay communication; coordination.

Private information can inspire communication or deception. In economic theory, mere words may achieve some communication, but the possibility of deception implies that full efficiency cannot be achieved (Myerson and Satterthwaite, 1983). In several experiments, however, communication allows bargaining parties in games with private information to capture greater gains from trade than can be obtained in any theoretical equilibrium (e.g., Hoffman and Spitzer, 1982; Radner and Schotter, 1989).

We provide further experimental support for the efficiency-enhancing effects of communication. More importantly, we analyze how the parties achieve this efficiency gain. We show that the conventional empirical representation of a player’s strategy (such as buyer’s bid as a function of buyer’s value) is inadequate. Explaining our evidence requires what we call a “dyadic” strategy: a single mapping from the two players’ value-cost types to their bid-ask actions.

We present an experiment involving a double auction with two-sided private information. A buyer and a seller simultaneously submit an offer and a demand, respectively. If the buyer’s offer exceeds the seller’s demand, then trade occurs at a price halfway between the two; otherwise, no trade occurs. After the parties learn their valuations but before they bargain, we allow written communication, face-to-face communication, or no communication. The written and face-to-face communication treatments allow “cheap talk” (Crawford and Sobel, 1982): the parties can make any claims that they like, including claims about their valuations, but they are not able to verify their claims.

We analyze the case in which the buyer’s value and the seller’s cost are independent draws from a uniform distribution. For this case, Chatterjee and Samuelson (1983) derived a linear equilibrium of the double auction without preplay communication, and Myerson and Satterthwaite derived an upper bound on the expected gains from trade in the double auction with preplay communication. Strikingly, Myerson and Satterthwaite showed that their upper bound on the expected gains from trade with communication can be achieved by the Chatterjee–Samuelson linear equilibrium without communication. Thus, cheap talk preceding a double auction may matter, in the sense of producing equilibrium outcomes that cannot arise as equilibria without communication (Farrell and Gibbons, 1989; Matthews
and Postlewaite, 1989), but game theory predicts that talk cannot help, in the sense of capturing greater gains from trade than the best equilibrium available without communication.

We find that the incidence of trade in our communication conditions is higher than both the measured incidence in our no-communication condition and the theoretical incidence in the linear equilibrium. Our primary contribution is an analysis of how the players achieved this increased efficiency in the communication conditions. As a first step, we estimate the conventional empirical representations of the players’ strategies, such as buyer’s bid on buyer’s value. This approach suggests that the parties played strategies akin to those of the linear equilibrium. But the players cannot have played anything like the linear equilibrium strategies, because they distinctly surpassed that equilibrium’s predicted incidence of trade. Instead, we find that these conventional empirical representations of the parties’ strategies suffer from omitted-variable and/or simultaneity bias, as follows. After communication, buyers base their bids not just on their own values, but also on their estimates of the seller’s cost, so the latter is an omitted variable in the conventional strategy regression for buyers (and analogously for sellers). Furthermore, after communication, buyers and sellers often coordinate on a single price, so the buyer’s bid can be seen as a function of the seller’s ask and vice versa—a system of equations. Finally, and most importantly, we show that these omitted-variable and simultaneity biases in the conventional strategy regression are not just econometric niceties; such communication and coordination allow the parties to capture greater gains from trade than can be obtained in any equilibrium.

We proceed as follows. Section 1 presents the existing theory of double auctions with two-sided private information with and without communication. Section 2 describes our experimental design and the findings from our study. Section 3 discusses the mechanisms through which communication might increase efficiency in bargaining with private information in our experiment and beyond.

1. THEORY

Our experiments involve a trading game in which a buyer and a seller have private information about their valuations for a particular good. We focus on the role of communication in improving the efficiency of trading outcomes, but for ease of exposition we begin our theoretical analysis with the case in which communication is not possible.
1.1. A Double Auction without Preplay Communication

The trading game that we study is a double auction. The seller names an asking price, $p_s$, and the buyer simultaneously names an offer price, $p_b$; if $p_b \geq p_s$, then trade occurs at the midpoint price, $p = (p_b + p_s)/2$, but if $p_b < p_s$, then no trade occurs. We denote the buyer’s valuation for the good by $v_b$; the seller’s, by $v_s$. If the buyer gets the good for price $p$, then the buyer’s payoff is $v_b - p$; if there is no trade, then the buyer’s payoff is 0. If the seller sells the good for price $p$, then the seller’s payoff is $p - v_s$; if there is no trade, then the seller’s payoff is 0. We assume that both parties are risk neutral.

The parties’ valuations are private information and are drawn from independent uniform distributions between 0 and 1. The presence of this private information means that a strategy for (say) the buyer in the double auction is a function specifying the price that the buyer will offer for each of the buyer’s possible valuations. As in a game without private information, a pair of strategies is an equilibrium of the double auction if each party’s strategy is a best response to the other party’s strategy.

There are many equilibria of the double-auction game. For example, there is a continuum of so-called “one-price” equilibria, in which trade occurs at a single price if it occurs at all. To illustrate a particular one-price equilibrium, consider an arbitrary value $x$ in [0, 1]. Let the buyer’s strategy be to offer $x$ if $v_b > x$ and to offer 0 otherwise, and let the seller’s strategy be to demand $x$ if $v_s > x$ and to demand 1 otherwise. Given the buyer’s strategy, the seller’s choices amount to trading at $x$ or not trading; thus the seller’s strategy is a best response to the buyer’s strategy, because the seller types who prefer trading at $x$ to not trading do so, and vice versa. The analogous argument shows that the buyer’s strategy is a best response to the seller’s, so these two strategies are an equilibrium. In this one-price equilibrium, trade occurs for the $(v_s, v_b)$ pairs indicated in Figure 1; trade would be efficient for all $(v_s, v_b)$ pairs such that $v_b \geq v_s$, but does not occur in the two shaded regions of the figure.

Chatterjee and Samuelson show that the following linear strategies are also an equilibrium of the double auction: the buyer’s offer is

$$p_b(v_b) = \frac{2}{3} v_b + \frac{1}{12},$$

and the seller’s demand is

$$p_s(v_s) = \frac{2}{3} v_s + \frac{1}{4}.$$
Recall that trade occurs in the double auction if and only if $p_b \geq p_s$. Manipulating (1) and (2) shows that $p_b > p_s$ in the linear equilibrium if and only if $v_b - v_s \geq 1/4$, as shown in Figure 2.

Figures 1 and 2 show that the most valuable possible trade (namely, $v_s = 0$ and $v_b = 1$) occurs in both the one-price equilibrium at price $x$ and the linear equilibrium. But the one-price equilibrium at price $x$ misses some valuable trades (e.g., $v_s = 0$ and $v_b = x - \varepsilon$, where $\varepsilon$ is small) and achieves some trades that are worth next to nothing (e.g., $v_s = x - \varepsilon$ and $v_b = x + \varepsilon$). The linear equilibrium, in contrast, misses all trades worth next to nothing but achieves all trades worth at least $1/4$. This suggests that the linear equilibrium may dominate any one-price equilibrium, in terms of the total expected gains that the two players receive, but also raises the possibility that the players might achieve even higher expected gains from trade in an alternative equilibrium.

The fact that trade occurs if and only if the buyer’s value exceeds the seller’s cost by at least $1/4$ implies that buyers with values below $1/4$ will not trade, and neither will sellers with costs above $3/4$. Figure 2 also illustrates this fact; seller types above $3/4$ make demands above the buyer's highest offer, $p_s(1) = 3/4$, and buyer types below $1/4$ make offers below the seller's lowest offer, $p_b(0) = 1/4$. Indeed, seller types above $3/4$ make demands below their costs, and buyer types below $1/4$ make offers above their values. These behaviors are rational only because such types know that they will not trade. It would also be equilibrium behavior for such types to offer/demand their values/costs.
Our main focus is not on comparing equilibria in the absence of communication, but rather on the role of communication in improving the efficiency of trading outcomes. To study this, we conduct both the double auction described above and an expanded game in which a double auction is preceded by an opportunity for the players to communicate, as follows.

1.2. A Double Auction with Preplay Communication

There are again many equilibria of the double auction with preplay communication. Some of the equilibria are easy to characterize. If each side is either silent or uninformative in the communication phase, then the double auction proceeds as just analyzed without communication; therefore, all of the equilibria of the double auction without communication continue to be equilibria of the expanded game with communication. Of course, our interest in preplay communication stems from the possibility of accurate information exchange resulting in new equilibria, not from replicating no-communication equilibria when cheap talk is allowed. Unfortunately, deriving even one new equilibrium of the expanded game requires a formal model of the opportunity that the players are given to communicate—who can say what when. Such a derivation would be intractable for many of the rich communication opportunities of interest, but one simple case has been analyzed by Farrell and Gibbons (1989) and by Matthews and Postlewaite (1989), who allow one simultaneous exchange of messages to precede the double auction.
One potential role for such preplay communication is equilibrium creation. Farrell and Gibbons explore this role for communication; they show how communication can allow information exchange that changes the parties' beliefs, thereby making it rational to play strategies in the ensuing double auction that are not equilibrium strategies in the double auction without preplay communication. A second potential role for preplay communication is equilibrium selection. Matthews and Postlewaite exploit this role for communication; they show how communication can allow different \((v_b, v_c)\) pairs to play different one-price equilibria, (as opposed to all \((v_b, v_c)\) pairs playing a given one-price equilibrium, as described in the previous subsection).

Beyond the Farrell–Gibbons and Matthews–Postlewaite analyses, little has been done to derive new equilibria of double auctions preceded by specific communication opportunities. But Myerson and Satterthwaite (1983) prove a general result concerning all communication opportunities. They show that the linear equilibrium of the double auction without communication yields higher total expected gains for the two players than any other equilibrium of an expanded game in which a double auction is preceded by any opportunity for communication—whether the communication is simultaneous (as in Farrell–Gibbons and Matthews–Postlewaite), sequential, or anything else.

We now present an experiment in which participants play double auctions with and without preplay communication. We find that without communication, trade occurs roughly as predicted by the linear equilibrium. With communication, however, trade occurs more often, contrary to the Myerson–Satterthwaite theory. More importantly, we also find that players achieve this increased efficiency by coordinating on a single price (as a function of their value-cost types), reminiscent of the Matthews–Postlewaite analysis. Myerson and Satterthwaite's results imply that the increased efficiency in our data cannot arise in any equilibrium, so the coordination that we observe in our communication conditions must somehow go beyond the equilibrium selection argument of Matthews and Postlewaite. We explore this puzzle.

2. METHOD AND RESULTS

2.1. Experimental Method

One hundred and two undergraduates from five Boston-area universities participated in one of six experimental sessions. Participants were recruited through university newspaper advertisements and postings around the campuses. Each session involved students from several universities. At
the beginning of each session, all of the participants (14 or more per session) were asked whether they knew anyone else in the room. The few participants who knew each other were then assigned the same role (e.g., buyer), so all interactions were carried out between strangers. Participants never bargained with the same partner more than once.

The experiment was a $3 \times 2$ design varying prebid communication (no prebid communication/written/face-to-face) and feedback (no-feedback/feedback). Details regarding the six communication-feedback treatments are provided below. A given participant was assigned to a single role (buyer or seller) and a single treatment for the entire experiment. Only one treatment was run in each experimental session. The structure of the bargaining game was constant across treatments; regardless of the presence of feedback or the presence or medium of prebid communication, the bargaining game was a double auction involving private submission of sealed bids/asks.

At the beginning of each session, buyers and sellers were separated into two rooms. All participants received envelopes containing materials for the task. Participants were told to read only the first sheet and to look at the next sheet in the envelope only when instructed to do so. The first sheet was an overview containing general information and describing the single communication-feedback treatment in which the player was participating.

The overview sheet stated that buyers would have the opportunity to purchase a fictitious commodity called Tynar from the sellers. Players were told they would participate in a number of rounds, each with a different partner. Each player participated in seven auctions, but players were not told the exact number of rounds they would play, to minimize end-game effects. The overview sheet stated that in each round the buyer’s value and the seller’s cost for Tynar were determined by independent draws from a uniform distribution from $0 to $50 in $1 increments. It was stated that the buyer’s value could be above, below, or equal to the seller’s cost. All participants were informed that the values and costs were private information. For example, the buyers were told, “Only you will know your value, and only the seller will know his or her cost.”

The overview sheet explained the rules for a double auction, and stated that this mechanism would determine the final trading price: “The price at which Tynar is traded (if it is traded)…is determined jointly by the Buyer’s Bid and the Seller’s Asking Price. As long as the Buyer bids more than the Seller is asking, the trade will occur at the midpoint. For example, if the Buyer bids $10 and the Seller asks $5, the trade will occur at $7.50 [(10 + 5)/2].” Buyers were told that any positive difference between their

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3 See the Appendix for sample materials. A full set of experimental materials is available from the first author upon request.
value for Tynar and the trading price would be their profit for that round. Similarly, sellers were told that any positive difference between the trading price and their cost for the Tynar would be their profit for that round. The instructions stated that if the buyer bought Tynar at a price higher than his or her value, then he or she would lose money in that round. Analogously, sellers were told they would lose money if they sold the Tynar for less than their cost. If no trade occurred, then no profit or loss would be realized. Participants in both roles were given three examples describing seller’s cost, buyer’s value, seller’s ask, buyer’s bid, seller’s earnings, and buyer’s earnings. In one example, both players made money. In another example, there was no trade. In the final example, one player lost money. (In the buyer’s overview it was the buyer that lost money, and in the seller’s overview it was the seller that lost money.)

The overview sheet explained that the participants would be rewarded with real money. Both hourly and incentive payments were provided. All participants were paid a base rate of approximately $6.67/hour for participating in the study. Players were told that, in addition to the base pay, there was a potential for incentive earnings based on individual profits in three randomly selected payoff rounds. The expected value of the incentive payment was $6.25 per round, or $18.75 for the session. Actual incentive payments ranged from $0 to $68.

After everyone finished reading the overview sheet, there was a question-and-answer session, segregated by buyer or seller role. When all questions had been answered, players completed a short questionnaire to check their understanding of the double-auction mechanism. All participants answered the questions correctly.

Each round occurred in four stages. In the first stage, players read a sheet providing their private value or cost. The second stage contained the communication treatment. The third stage was the private submission of a sealed bid or ask. In the fourth and final stage, players were provided feedback about the outcome of the auction (in the feedback treatments only). At the end of this stage, a new round began. After all rounds had been completed, three rounds were randomly selected to be the payoff rounds.

The communication allowed between buyers and sellers in the second stage (if any) occurred after the players learned their values/costs but before they submitted their bids/asks. Participants in the no-communication treatment played anonymously, could not see one another, and could not communicate with one another at any time during the experiment.

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4 This information seemed clear to the players: No player lost money in any round.

5 $10 base pay for approximately 1.5 hours in the no-communication treatments; $20 base pay for approximately 3 hours in the written and face-to-face treatments.
Players in this condition were given two minutes to think about their strategies before submitting their bids/asks. In the written-communication treatment, players were given a 13-minute communication period in which they were permitted to exchange written messages with their partner for the round, on sheets provided in their envelopes. The buyers and sellers in the written condition were physically separated, and all interactions were anonymous; couriers delivered all messages between the players. No constraints were placed on what players could write in these messages. All written messages were collected and saved. Participants in the face-to-face-communication treatment were allowed a 6-minute communication period, in which the buyer and the seller could meet and talk. No restrictions were placed on participants’ conversations, but the players were restricted from bringing their valuation sheets with them to the discussion, to eliminate the potential for physical evidence that could document a claim about cost or value. All face-to-face interactions were audiotaped. Buyers and sellers in the face-to-face communication treatments returned to their separate rooms at the end of each 6-minute communication period to submit bids/asks.

The bid/ask stage was identical in all treatments and rounds. Buyers and sellers, separated by room and seated at desks spaced so that no one’s submission was visible to anyone else, wrote their bid/ask on a sheet provided and gave it to the experimenter. Buyers were told that the bid should represent the maximum they would be willing to pay the seller for Tynar, and that the statement of a bid meant they would be willing to purchase Tynar for any price less than or equal to the price they listed. The instructions to sellers were entirely analogous. Players were told they could submit only a specific monetary value for a price; no other terms or conditions could be specified. Following the submission of a bid/ask, in each round each player was asked to write down his or her best estimate of the other party’s valuation.

The timing and type of information provided in the final stage varied by feedback treatment; details for the appropriate treatment were provided in the overview sheet. In the feedback treatment, participants were given written feedback after each round stating (a) whether or not a trade occurred in the double auction just completed; (b) if so, at what price; and (c) his or her own profit for that round. Players in the no-feedback treatment received feedback regarding trade, price, and individual profit only after all rounds had been completed, and only for the three payoff rounds. Players in both treatments were informed that they would never be told the profit of the other party. Payments to participants were made in the separate buyer/seller rooms and were staggered—buyers first and sellers second—so that buyers and sellers exited the building at different times. Players were informed of these steps before the experiment, to
make it clear that they would not have to meet the other party again after bargaining.

2.2. Results

We first present evidence about trade outcomes. We then turn to evidence regarding the bidding strategies used to achieve these trade outcomes.

2.2.1. Trade Outcomes. Because the parties’ valuations were drawn randomly, the buyer’s value was below the seller’s cost in some observations, so trade was not expected to occur (and did not). Of the 343 observations, 192 had $v_b > v_s$. Unless noted otherwise, we restrict attention to these 192 observations.

Figure 3 plots the trade outcomes for the no-communication, written, and face-to-face treatments. (As we show below, neither feedback nor round affect efficiency, so both feedback conditions and all rounds are included in each figure.) Each graph in the figure shows the 45-degree line ($v_b = v_s$) and the line below which the Chatterjee–Samuelson linear equilibrium predicts that trade will not occur ($v_b = v_s + 12.5$). Figure 3(A) shows that the trade predictions of the linear equilibrium are fairly accurate for our no-communication condition, but Figures 3(B) and 3(C) show that the linear equilibrium fits the data less well for our communication conditions, largely because there are many trades in the Chatterjee–Samuelson no-trade region in these conditions. Table I presents these data in numeric form. In the no-communication treatments, 89% of the high-value ($v_b > v_s + 12.5$) trades were achieved but only 11% of the low-value ($v_s < v_b < v_s + 12.5$) trades were achieved. In aggregate over the no-communication observations, 82.3% of the total available surplus was captured through trade. In the written treatments, a slightly lower fraction (83%) of high-value trades was achieved, but a much higher fraction (44%) of low-value trades was achieved. We explore both of these differences between the no-communication and written treatments. In aggregate, 77.7% of the available surplus was captured in the written treatments, less than was captured in the no-communication treatments. In the face-to-face treatments, the fractions of trades achieved were significantly higher than equilibrium for both high-value and low-value trades (94% and 74%, respectively), and nearly all of the available surplus was captured (94.1%). We also explore these differences from the no-communication conditions.

Because we have random draws of value pairs, it is possible that any findings concerning trade incidence are confounded by differences in the gains from trade ($v_b - v_s$) across conditions. To assess this possibility, we ran logistic regressions on the 192 observations with positive gains from trade. The dependent variable is whether or not trade occurred. The
FIG. 3. Trade outcomes ($GFT > 0$).
Table I
Trade Outcomes by Communication Treatment

<table>
<thead>
<tr>
<th></th>
<th>$v_i &gt; v_s + 12.5$</th>
<th>$v_i &lt; v_b &lt; v_s + 12.5$</th>
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<tr>
<td>No communication treatments</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(with and without feedback)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No trade</td>
<td>4 (11%)</td>
<td>25 (89%)</td>
<td>29 (46%)</td>
</tr>
<tr>
<td>Trade</td>
<td>31 (89%)</td>
<td>3 (11%)</td>
<td>34 (54%)</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>28</td>
<td>63</td>
</tr>
<tr>
<td>Written treatments</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(with and without feedback)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No trade</td>
<td>6 (17%)</td>
<td>19 (56%)</td>
<td>25 (36%)</td>
</tr>
<tr>
<td>Trade</td>
<td>30 (83%)</td>
<td>15 (44%)</td>
<td>45 (64%)</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>34</td>
<td>70</td>
</tr>
<tr>
<td>Face-to-face treatments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(with and without feedback)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>No trade</td>
<td>2 (6%)</td>
<td>7 (26%)</td>
<td>9 (15%)</td>
</tr>
<tr>
<td>Trade</td>
<td>30 (94%)</td>
<td>20 (74%)</td>
<td>50 (85%)</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>27</td>
<td>59</td>
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regressors are the gains from trade, two dummy variables for written and face-to-face communication conditions, a dummy variable for the feedback condition, and the round number (entered as a continuous variable). The results are presented in column 1 of Table II. The coefficient on face-to-face communication is positive and significant; the coefficient on written communication is positive but only marginally significant. The estimated coefficients on feedback and round are both positive but not significant. Adding the feedback*round interaction to this regression changed nothing of interest.

The insignificant coefficients on feedback and round in this logistic regression suggest that little learning occurs. This is a conservative test, however, since in the majority of the observations trade should occur and does; therefore, there is little opportunity for learning. As a less conservative test, we ran the same logistic regression on the subsample of observations where $v_s < v_b < v_s + 12.5$. As shown in column 2 of Table II, the estimated coefficients on feedback and round are again positive but not significant. On this subsample, however, the estimated coefficients on not only face-to-face but also written communication are positive and significant. Adding the feedback*round interaction to this regression changed nothing of interest.

2.2.2. Bidding Strategies. To determine how the parties achieved a higher incidence of trade in the communication conditions, we turn next to their bidding strategies. We first review “individual” strategies in the no-communication and communication conditions and then focus on “dyadic” strategies in the communication conditions. In all our analyses of
individuals, the qualitative results for buyer behavior are identical to those for seller behavior. Thus we say nothing in the text about the results for the sellers, but provide full information about both parties in the figures. In our analysis of the no-communication condition we use data from all observations, not just the observations with positive gains from trade. In the communication conditions we restrict attention to the observations with positive gains from trade. Later we provide evidence that the parties often used the communication phase to exchange fairly accurate information on their valuations. We thus restrict attention to the observations with positive gains from trade, because bids and asks when gains from trade are known to be negative may be hard to interpret.

<table>
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</tbody>
</table>

Note: Column (1) uses all observations with positive gains from trade; column (2) uses only those with \( v_i < v_s + 12.5 \).
We begin by comparing the players’ strategies to those of the linear equilibrium. For observations in the no-communication treatment, Figure 4(A) shows the 45-degree line \( p_b = v_b \), the buyer’s strategy in the linear equilibrium \( p_b = 0.67v_b + 4.16 \), and the regression line through the buyers’ bids \( p_b = 0.72v_b + 1.11 \). Figure 4(B) presents the analogous

\[\text{FIG. 4. Bidding strategies, no communication treatments.}\]
information for the seller; we follow this expositional convention hereafter. On the full sample, this buyer's strategy regression is statistically different from the linear equilibrium strategy (F(2,110) = 49.27, p = 0.0000), but the economic difference between the two is small. Furthermore, the buyer's strategy in the linear equilibrium has the counterintuitive feature that buyers with valuations \( v_b < 12.5 \) are indifferent about their bids as long as they do not exceed 12.5, so we reestimated the buyer's strategy on the subsample of buyer values satisfying \( v_b > 12.5 \). On this subsample (of 85 observations), the regression line is \( p_b = 0.68v_b + 2.47 \), which is again statistically different from the linear strategy (F(2,83) = 6.40, p = 0.0026) but is even closer economically.

Figure 5(A) shows buyers' bids in the written-communication treatment. Curiously, the strategy regressions for written communication are even closer to the linear equilibrium (both statistically and economically) than they were for no communication. On the entire sample, the regression line (\( p_b = 0.69v_b + 2.50 \)) is not statistically different from the linear equilibrium (F(2,68) = 1.33, p = 0.272). But the parties cannot have produced the trading outcomes shown in Figure 3(B) and Table I by playing the linear equilibrium strategies in the written condition, because the linear equilibrium implies no trade when \( v_i < v_h < v_i + 12.5 \).

We find qualitatively similar results for face-to-face communication, as shown in Figure 6(A). For the whole sample, the regression line (\( p_b = 0.60v_i + 4.06 \)) is statistically different from the buyer's strategy in the linear equilibrium (F(2,57) = 5.21, p = 0.0084). But this regression for the face-to-face treatments is approximately as close (both statistically and economically) to the linear equilibrium strategy as the no-communication regression was earlier. In particular, had the parties played these estimated strategies in the face-to-face treatments, the trade outcomes would not have been nearly as efficient as those reported in Figure 3(C) and Table I. Apparently, in our two communication conditions, something else is determining the players' bids, beyond their individual valuations.

2.2.3. Dyadic Strategies. We now turn to analyses that investigate the strategies of the two players as a dyad, where the variable of interest is the relationship between the players' strategies. In 73 of the 129 dyads with positive gains from trade in the communication conditions, the buyer and seller named exactly the same price. We say that these dyads “coordinated on a single price.” In 8 of the 129 dyads, the parties seemed to reveal their valuations to each other. (Recall that during the bid/ask phase in each round, each party was asked to estimate the other's valuation. In some cases, one party's estimate is equal to the other's valuation. We assume that such precise estimates result from truthful information exchange in
the preplay communication stage.) When both parties in a given dyad gave precisely correct estimates of the other’s valuation, we say that “mutual revelation” occurred. Figure 7 summarizes these dyadic behaviors. In total, 75 of the 129 dyads with positive gains from trade in the two communication conditions engaged in coordination on a single price and/or mutual revelation.

FIG. 5. Bidding strategies, written treatments.
FIG. 6. Bidding strategies, face-to-face treatments.

These findings suggest potential omitted-variable and/or simultaneity biases in our earlier regressions of buyers’ bids on their values. For example, if we regress buyer’s bid on buyer’s value for the 129 observations with communication and positive gains from trade, then the regression line is $p = 0.65v + 3.24$ and the $R^2 = 0.57$. But if we add seller’s cost and seller’s ask to this regression, then the regression line is $p = 0.25v + 0.10c + 0.57a - 0.52$ and the $R^2 = 0.85$ (and the two new regressors are individually significant). This regression is not intended as a structural
FIG. 7. Dyadic behaviors.

2.2.4. Coordination. Figure 7 shows that coordination on a single price occurred in 28 of the 70 dyads with positive gains from trade in the written-communication treatment and in 45 of the 59 dyads with positive gains from trade in the face-to-face communication treatment. By chance, there was also coordination on a single price in 3 of the 63 observations in which trade occurred in the no-communication treatment. As discussed in Section 1.1, coordination on a single price is an equilibrium of a double auction without communication. Moreover, as discussed in Section 1.2,
Matthews and Postlewaite show how communication can allow different \((v_b, v_r)\) pairs to play different one-price equilibria. But all of these equilibria (with and without communication) are still subject to Myerson and Satterthwaite’s upper bound on the efficiency of any equilibrium (namely, the efficiency of the Chatterjee–Samuelson linear equilibrium), whereas our results suggest that coordination was a key factor in allowing our participants to outperform the Myerson–Satterthwaite upper bound.

Recall the logistic regressions reported in Table II, in which the dependent variable is whether trade occurred and the regressors of interest are gains from trade and dummy variables for the written and face-to-face conditions. On the full sample (of 192 observations with positive gains from trade), the estimated coefficient on written communication is positive and marginally significant, and the estimated coefficient on face-to-face communication is positive and highly significant. When we restrict this analysis to the subsample (116 observations) for which coordination did not occur, communication is not significant (written, \(p = 0.197\); face-to-face, \(p = 0.336\)). That is, we find no significant differences between the no-communication and communication treatments for dyads who do not coordinate on a single price. In this sense, price coordination is key to our finding that communication yields higher efficiency.

As a further exploration of this issue, we also ran a linear-probability regression, i.e., an ordinary least squares (OLS) regression in which the dependent variable is whether trade occurred. As in Table II, here regressors are gains from trade and dummy variables for the written and face-to-face treatments. But in this regression we add the interactions of these three variables with a dummy variable equal to 1 if price coordination occurred. Now the coefficient for written communication is small, negative, and marginally significant and the coefficient for face-to-face is very small and insignificant, but the interaction of written and coordination is large, positive, and highly significant, as is the interaction of the face-to-face and coordination. Unlike the logistic regression (which cannot include a dummy variable for coordination, because it perfectly explains the dependent variable for all 76 observations in which coordination occurred), the linear probability model can include the coordination dummy, such as in the interaction terms reported earlier. Including variables reflecting coordination allows us to show that the written and face-to-face dummies are significantly different for the dyads that coordinate versus those that do not. Face-to-face and written communication increase the likelihood of trade only in those dyads that coordinate. This regression also suggests that for those who do not coordinate, written communication slightly reduces the likelihood of trade relative to no communication; we return to this later.
Given the importance of coordination in creating the efficiencies we observe, we examined how our treatments affected the likelihood of coordination. In a logistic regression on the 192 observations with positive gains from trade, the dependent variable is whether or not coordination occurred and the regressors are gains from trade, two dummy variables for written and face-to-face treatments, a dummy variable for feedback, and round number. The overall regression is significant ($\chi^2 = 91.10, p < 0.0005$), as are the coefficients for the communication treatments (written: $\beta = 2.932, z = 4.392, p < 0.0005$; face-to-face: $\beta = 4.540, z = 6.620, p < 0.0005$), feedback ($\beta = 1.170, z = 2.944, p = 0.003$), and round ($\beta = 0.248, z = 2.454, p = 0.014$). The coefficient for gains from trade is not significant ($\beta = 0.034, z = 1.895, p = 0.058$). The estimated coefficient for the written treatment is significantly different from that for face-to-face ($\chi^2 = 14.54, p < 0.005$). When the feedback*round interaction is added to the regression, the regression remains highly significant, as do the two coefficients for the communication, but feedback is no longer significant ($z = 1.335, p = 0.182$), and the round is only marginally significant ($z = 1.835, p = 0.066$). The coefficient for the interaction term is not significant ($z = -0.034, p = 0.973$). Both communication treatments make coordination more likely than no communication, but coordination is significantly more likely to occur face-to-face than in writing.

2.2.5. Revelation and Deception. Mutual revelation occurred in 3 of the 70 observations in the written treatment and in 5 of the 59 observations in the face-to-face treatment. While mutual revelation of values does not determine the parties' bids, in 7 of the 8 cases of mutual revelation the parties traded at a price that equally distributed the profits between the two players (rounding to the nearest dollar). In 6 of these 7 cases, the parties coordinated on the single price that resulted in equal distribution of the surplus.

While we assume that a correct estimate of the other's valuation results from honest revelation, we cannot assume that an incorrect estimate results from deception. To measure deception directly, we used the transcripts of the written and face-to-face interactions using all observations, not just the 129 with positive gains from trade. We coded the behavior of each player into one of three categories of information exchange: (1) honest revelation of value; (2) no revelation but no misrepresentation; and (3) misrepresentation of value. There is a significant difference in the overall pattern between the two communication treatments ($\chi^2 = 6.198, p = 0.045$). This result is driven mainly by differences in misrepresentation ($\chi^2 = 5.611$ (buyer), $p = 0.018$ and $\chi^2 = 15.581$ (seller), $p < 0.001$). Simply put, players were more likely to lie in writing than face to face. An example from the written transcripts is illustrative. (Seller) “Let’s get down
to business. We are here to earn money, right? So, we’ll have to negotiate. Let’s be straight and honest. My cost is $19” (actual cost = $8). In writing, 48% of the sellers and 41% of the buyers explicitly misrepresented their values. In contrast, in face-to-face communication, only 22% of the sellers and 26% of the buyers misrepresented their values. This difference is also reflected in dyadic behaviors. Using the costs and values revealed in the transcripts, we find that 31% of the dyads mutually revealed when the interaction was face-to-face, while only 17.9% of them mutually revealed when the interaction was in writing (χ² = 11.692, p < 0.001).

3. DISCUSSION

We take up the problem of communication in bargaining where most earlier prior studies leave off. Others show that unstructured communication improves the outcome of bargaining games, but do not explore how it matters. Our findings suggest that the bargaining pair works together to achieve a mutually beneficial outcome. The bids and asks appear to be determined dyadically, by the pair, rather than independently, by the individuals. In light of this finding, we assert that a theory of interactive bargaining with communication should incorporate not only individual, but also dyadic behavior.

We document two efficiency-improving dyadic strategies: coordination on a price and mutual revelation of values. We also explore how different communication media (written versus face-to-face) affect bargaining efficiency. Recall that bargaining in the written treatment was more efficient than that in the no-communication treatment only when potential gains from trade were small. When potential gains from trade were large, bargaining in the written treatment was less efficient than when no communication was permitted. The sources of these differences between the written and no-communication treatments are now clear: Higher efficiency is the result of dyadic coordination, as shown in the regression presented in Section 2.2.4, while lower efficiency is the result of high rates of deception in the written treatment, as shown in Section 2.2.5. In contrast, bargaining was more efficient in the face-to-face treatment than in the no-communication treatment in both large and small zones of trade. This increased efficiency is achieved through high levels of coordination, not compromised by deception, when parties interact face-to-face.

In some of their experiments, Radner and Schotter (1989) studied precisely our environment: two-sided private information about a buyer’s value and a seller’s cost, each drawn independently from a uniform distribution. Like us, they conducted double auctions without preplay communication. They also conducted an experiment that allowed commu-
communication to occur, but did so using an unstructured negotiation in which face-to-face communication and bargaining occurred concurrently, rather than having communication precede a fixed bargaining game (in our case, a double auction). In the no-communication case, Radner and Schotter found behavior much like we found. In the communication case (with unstructured negotiation), they found essentially full efficiency—99% of the potential gains from trade were achieved. This finding about trade outcomes is again in keeping with ours: Face-to-face communication greatly improves performance.

But Radner and Schotter (1989) provide no analysis of the sources of this efficiency. Instead, they pose a series of questions (p. 210):

The success of the face-to-face mechanism, if replicated, might lead to a halt in the search for better ways to structure bargaining in situations of incomplete information. It would create, however, a need for a theory of such unstructured bargaining in order to enable us to understand why the mechanism is so successful…The answers to such questions will have to be pursued elsewhere.

Our experiments show that it is not unstructured bargaining, but rather the potential for coordination in interpersonal communication that produces the dramatic improvement in efficiency. We restricted communication to the preplay phase, but still found greatly enhanced efficiency effects.

Valley, Thompson, and Bazerman (2000) (hereafter VTB) also study a double auction with private information. The differences between our study and theirs suggest a refinement of the general conclusions that communication improves efficiency through dyadic strategies, and more so face-to-face than in writing. VTB used the same protocol that we present here, but they collected their data in a classroom, so that all interactions were carried out between acquaintances or friends. In our study, we observe higher levels of coordination and higher levels of trade with face-to-face communication than with written communication. But VTB observe no such differences across treatments; the parties achieved nearly full efficiency in both the written and the face-to-face treatments (but, as in our study, VTB find lower efficiency when no communication was allowed). Recall that the participants in our study were strangers, whereas the players in VTB had preestablished and ongoing relationships because of their participation in the same semester-long course. The differences between the two studies suggest a potential interactive effect between communication medium and social knowledge, where face-to-face and written communication forms are equally useful for promoting efficiency when social knowledge is present.

Valley, Moag, and Bazerman (1998) (hereafter VMB) also find that face-to-face bargaining involves not only greater efficiency, but also less
deception than bargaining in other media. VMB studied a different environment—a variation on Akerlof’s (1970) “lemons” environment, where (i) the seller knows \( v_s \), (ii) the buyer knows that \( v_b = (3/2)v_s \), but (iii) the buyer knows only the distribution of \( v_s \) (which is uniform on \([0, 100]\)), not the actual value of \( v_s \) or \( v_b \). VMB introduce written, telephone, and face-to-face communication into this variant of the “lemons” environment. As in Radner and Schotter’s communication treatment, VMB allow unstructured negotiation rather than allowing only preplay communication before a specific bargaining game. They report direct measures of seller misrepresentation and buyer trust. VMB find a high incidence of seller misrepresentation and low levels of buyer trust in written bargaining; as a result, the modal outcome is impasse (as predicted in equilibrium). In telephone bargaining, seller misrepresentation is high, but so is buyer trust; the modal outcome is the winner’s curse. In face-to-face bargaining, seller misrepresentation is low and buyer trust is high; the modal outcome is mutually profitable agreement. Notably, parties bargaining face to face achieved nearly full efficiency.

Prior explanations of the effects of communication on bargaining are often based on social utility effects from communication, especially face-to-face communication (Dawes, 1988; Sally, 1995). A social utility explanation suggests that trusting and trustworthy behavior occurs during social interactions because players who communicate with one another develop an interest in the welfare of the other party, especially if the communication takes place face to face. In many plausible formal models of such a social utility effect, face-to-face interaction would lead to more equal distribution of surplus across the two parties than would written interaction, and both would lead to more equal distribution than no communication. For example, with social utility, one might get more trade via bidding functions that were closer to bidding one’s value, which would result in closer to equal splits of the surplus.

To explore the potential explanatory power of a social-utility explanation on our data, we created a variable indicating the distribution of profits across the two players, given agreement: absolute difference between buyer’s profits and seller’s profits, normalized by the total gains from trade. We regressed the profit-distribution variable on the two communication dummy variables, the feedback dummy, round, and dummy variables for coordination and mutual revelation. The overall regression is significant \((F(6,122) = 4.21, \ p = 0.0007; R^2 = 0.138)\), as are the coefficients for face-to-face communication \((\beta = 0.183, \ p = 0.020)\), written communication \((\beta = 0.188, \ p = 0.004)\), and mutual revelation \((\beta = -0.275, \ p = 0.030)\). Note that the estimated coefficients on the communication variables are positive, indicating that face-to-face and written communication increase the difference across the players’ profits relative to no communication.
There is no significant difference between the written and face-to-face treatments ($F(1,122) = 0.03, p = 0.869$). Only mutual revelation has a significant mitigating effect. Adding an interaction variable for feedback*round does not qualitatively affect the results. Similarly, Schotter (1995) reanalyzed Radner and Schotter’s (1989) data and found that the variability of the buyer’s share of surplus was substantially larger in unstructured face-to-face negotiations than in the sealed bid without communication. We find that both written and face-to-face treatments result in greater variability in distribution than no communication (Bartlett’s test for equality of variances: $\chi^2 = 11.008, p = 0.001$, face-to-face; $\chi^2 = 11.713, p = 0.001$, written). We find no difference in variances between the written and face-to-face treatments. Thus, parties are using the communication phase to coordinate and ensure trade, but not to ensure equal distribution of the surplus. These findings suggest that social utility explanations provide little insight into the heightened efficiency in the communication treatments.

Our findings belong to the large body of research suggesting that actual bargaining behavior deviates from traditional game-theoretic models. Whereas much of the literature on behavioral decision theory suggests that people fall short of fully efficient outcomes, our findings add to the growing literature suggesting that real behavior can lead to better performance than is predicted by traditional notions of rationality. We hope that this research prompts further exploration of positive aspects of human behavior, specifically social interaction, in addition to the negative aspects that have been identified in behavioral decision theory. We believe that when observed behavior clashes with game-theoretic predictions, researchers face a decision of whether to dismiss the observed behavior as due to chance, mishap, or methodological flaw or to reformulate the theory. Bargaining often occurs with some communication between the parties. If, as our findings suggest, this communication substantially changes the strategies chosen by the players, then the critical consequences of communication—coordination and honest revelation—need to be considered in future theories of bargaining.

APPENDIX

Study II Materials

*Tyntar Overview.* In this exercise, you will participate in a series of negotiations. In each negotiation, there will be a Buyer and a Seller. You will remain the same role in all negotiations.

7 Only face-to-face seller materials are presented here. Written and no-communication materials vary in the last two pages. A full set of materials is available from the first author.
negotiations. You will negotiate with a different person in each negotiation. Please read closely all of the information below. You will have an opportunity to ask questions about anything you do not understand.

In each negotiation, you will bargain over a fictitious commodity called Tynar. Buyers value Tynar at a given value, which will change in each negotiation. The Seller has a cost for Tynar, which will also change in each negotiation. The Buyer makes money by buying Tynar at a price lower than the given value. The Seller makes money by selling Tynar at a price higher than the given cost.

The Buyer's value and the Seller's cost are independent. Both, however, will be randomly drawn from the same distribution—$0-$50 (integers only). Thus the Buyer's value will change in each negotiation and can vary across negotiations from $0 to $50, inclusive. Similarly, the Seller will be given a new cost for Tynar each round, and the cost can vary across negotiations from $0 to $50, inclusive. The Buyer's value in any negotiation may be above, below, or equal to Seller's cost. Only the Buyer will know the Buyer's value and only the Seller will know the Seller's cost.

Each negotiation has the potential for earnings or losses up to $50 across the Buyer and the Seller.

The price at which Tynar is traded if it is traded in any negotiation is determined jointly by the Buyer's Bid and the Seller's Asking Price. As long as the Buyer bids more than the Seller is asking, the trade will occur at the midpoint. For example, if the Buyer bids $10 and the Seller asks $5, the trade will occur at $7.50 \((10 + 5)/2\).

If the Buyer bids $5 and the Seller asks $10, no trade occurs in that negotiation.

Buyers make a profit by trading at a price less than their value for the Tynar. Sellers make a profit by trading at a price higher than their costs.

Specifically:

\[
\text{Buyer Profit} = \text{Buyer Value} - \text{Trading Price} \\
\text{Seller Profit} = \text{Trading Price} - \text{Seller Cost}
\]

After the negotiations are over, a participant will randomly select 3 negotiations to be the payoff rounds. You will be paid whatever you earned in those 3 rounds. (This is in addition to the fee everyone will be paid for participating in the session.)

Below are some examples:

- **Seller's Cost:** $4.00  
  **Buyer's Value:** $22.00  
  **Seller's Asking Price:** $16.00  
  **Buyer's Bid:** $20.00  
  Buyer Bid > Seller Asking Price, so **Trading Price** = \((16.00 + 20.00)/2\) = $18.00  
  Seller earns \((\text{trading price} - \text{cost})\) or $18.00 - $4.00 = $14.00  
  Buyer earns \((\text{value} - \text{trading price})\) or $22.00 - $18.00 = $4.00  

- **Seller's Cost:** $20.00  
  **Buyer's Value:** $17.00  
  **Seller's Asking Price:** $20.00  
  **Buyer's Bid:** $17.00  
  No sale takes place, since Buyer Bid < Seller Asking Price  
  Seller earns: $0.00  
  Buyer earns: $0.00  

- **Seller's Cost:** $12.00  
  **Buyer's Value:** $10.00  
  **Seller's Asking Price:** $12.00
Buyer’s Bid: $13.00

Buyer bid more than Seller asked, so Trading price = ($13.00 + 12.00)/2 = $12.50
Seller earns (trading price − cost) or $12.50 − 12.00 = $0.50
Buyer earns (value − trading price) or $10 − 12.50 = (−$2.50) Notice: This is a loss to the Buyer. The Buyer lost only because s/he chose to make a Bid above his or her value for Tynar.

Be careful not to lose money in this exercise.
Please take this opportunity to ask the experimenter any questions you may have about the exercise.
After questions, before you begin the negotiations, please answer the questions on the next page.

Pre-negotiation Questions

1. If the Buyer’s value is $4.00 and the Seller’s cost is $5.00, is a mutually profitable trade possible?

2. If the Buyer’s value is $46.00, what’s the most s/he can bid for the Tynar and still be sure to make a profit if a trade occurs?

3. If the Seller’s cost is $12, what’s the lowest price s/he can ask and still be sure to make a profit if a trade occurs?

4. If the Buyer’s value is $32.00 and the Seller’s cost is $8.00, and the Buyer bids $26.00 while the Seller asks for $20.00, will a sale take place?
   If so, at what price?
   How much would the Buyer earn?
   How much would the Seller earn?

5. If the Buyer’s value is $13.00 and the Seller’s cost is $15.00, and a trade takes place at $16.00, how much does the Buyer earn?
   How much does the Seller earn?

Seller’s Negotiation and Payment Details. Each negotiation takes place in three steps: (1) You will be given a cost on your Seller Report Form for this negotiation; (2) You will communicate face-to-face with the Buyer; (3) After the communication period is over, you will go back to the seller classroom and submit a private Asking Price for the Tynar.
Specifically:

1. You have been given a cost from a random number generator. All integer values between 0 and 50, inclusive, are possible values for the Tynar. This cost is recorded under “Cost” on the Seller’s Record Sheet. These Record Sheets are on your assigned desk in the seller classroom. There is one Sheet for each negotiation. Look only at the Sheet for the upcoming negotiation. In other words, please do not look at the Record Sheet for any round other than the one you are about to negotiate.

2. The Record Sheet is not to be taken out of the Seller Classroom. You may want to note your partner’s id # and your cost for Tynar for the upcoming negotiation before you go out of the room to the negotiation.

3. Each seller has a pre-assigned negotiation space. This is noted on the Map and the locations are clearly marked in the hallways. The buyers will be rotating across sellers, but the sellers will always be negotiating in the same spot, throughout all of the negotiations.
4. You will need to bring the tape recorder with you to the first negotiation. After the first negotiation, and after all subsequent negotiations, please leave the recorder at the negotiation spot. Make sure you turn the recorder on at the start of each negotiation and off when the negotiation is over. Please announce the negotiation round number and the buyer's participant number at the beginning of each negotiation, after you have turned on the tape recorder.

5. You have 6 minutes to communicate face-to-face with the Buyer. You may talk about anything you would like during this communication period. After the 6 minutes are over, you must stop all communication.

6. At the end of the 6 minute communication period, please go back to the central seller classroom, to the seat you were assigned. On your desk is your Record Sheet for the negotiation just completed. Record your Asking Price on the Seller's Record Sheet. This Asking Price is the price at which you are willing to sell the Tynar. Your statement of Asking Price means you are willing to sell Tynar for any price more than or equal to the price you listed. This Asking Price is the minimum you are willing to accept for the Tynar. You may ask only a specific monetary value—in other words, no terms or conditions may be added to your Asking Price. Then, complete the rest of the Record Sheet, answering all the questions asked.

7. Bring the completed Record Sheet from the negotiation you just finished up to the front of the classroom. Please put the completed Record Sheet into the manila folder labeled with your participant role and number (e.g., Seller #2).

8. After turning in the Record Sheet for the negotiation you just finished, go back to your seat and look at the Record Sheet for the next negotiation. Look at your Pairing Sheet to see who will be your negotiation partner. On the Record Sheet, note your participant number and your partner's participant number, along with your name. Remember, you should NOT bring the Record Sheet for the upcoming negotiation with you to the negotiation.

At the same time as you submit your Asking Price, the Buyer will be submitting a private, sealed Bid for Tynar. The Bid will state the maximum s/he is willing to pay for the sale of Tynar. In order for any transaction to occur, the Buyer must bid as much as or more than the Seller is asking for the Tynar. If this occurs, the Tynar is sold at the price exactly midpoint between the Buyer's Bid and the Seller's Asking Price (the midpoint or average of the two values).

At the end of the series of negotiations, a participant will randomly select the 3 rounds for which you will be paid.

REFERENCES


