ECONOMIC RESEARCH REPORTS

MATCHING AND EFFICIENCY IN THE BASEBALL FREE-AGENT SYSTEM: AN EXPERIMENTAL EXAMINATION

by

Haig Nalbantian
and
Andrew Schotter
with the assistance of Ken Rogoza

R.R. # 90-05 January, 1990

C. V. STARR CENTER
FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

Matching and Efficiency in the Baseball Free–Agent System: An Experimental Examination

Haig Nalbantian
Andrew Schotter

with the assistance of
Ken Rogoza

October, 1989

The work on this paper was sponsored by the C.V. Starr Center for Applied Economics and the National Economic Research Associates, Inc.. We are grateful to Louis A. Guth and Richard Rozek for valuable suggestions and commentary. We give special thanks to Vicky Myroni who is responsible for writing all of the programs used.

Abstract

This paper presents the results of an experimental study investigating the problem of allocating heterogeneous indivisible objects using markets or market–like mechanisms. Some examples include the market for medical interns studied by Roth (1984a), where the problem is one of matching interns with hospitals, the problem of matching college students with dormitory rooms, or even the problem of matching high school graduates with colleges. In this paper we will take a look at another application of this matching problem –– the problem of matching profession baseball players (free–agents) with teams.

Section 1: Introduction

This paper presents the results of an experimental study of the problem of allocating heterogeneous indivisible objects or services using markets or market-like mechanisms. Examples include the problem of matching medical interns with hospitals, as studied by Roth (1984a), the problem of matching college students with dormatory rooms, or even the problem of matching high school graduates with colleges. In this paper, we consider another application of this matching problem: the market for free agents in Major League Baseball.

Our work is inspired by two sources: first, the rapidly growing literature on the "matching problem,", mostly generated by Al Roth (1982, 1984a, 1984b, 1985a); second, some current issues in the operation of Baseball's free agency system.

The literature on matching is concerned with the development of algorithms that can be used to match people with people or people with objects and with the incentive properties of the mechanisms defined by these algorithms. Accordingly, the first objective of our study is to place some empirical meat on the sophisticated skeletal structure developed by Gale and Shapely (1962), Roth, and others (namely, Shapely and Shubik (1972), Demange and Gale (1985), and Leonard (1983)). We wish to determine whether the incentive properties claimed in theory can be observed in the lab.

Our second objective is to investigate the market for free agents in the Baseball industry, a market comprised of heterogeneous and indivisible "goods" (the services of baseball players). We seek to compare and assess the efficiency and distributional properties of the current free agency system (and a particular, "complete information" variant of that system) and those of an alternative allocation mechanism whose inspiration can be found in the matching literature.

Our paper is organized as follows. In section 2, we review, briefly, the history of the free agency system. In addition, we outline the three alternative mechanism of interest. This is followed by a review of some of the matching literature. We then present the most important results of our study. Section 3 describes the actual experiments conducted. A detailed presentation of our results is contained in section 4, followed, in section 5, by a summary and discussion.

Section 2: The Free-Agent System

Until the mid 1970's, professional baseball players did not own the rights to their services. These rights were owned exclusively by the teams they were playing for so that when a player's contract expired he did not have the option of shopping around for a team to play with. His only option was to sign a contract with the team he was on or sit out the year. Alternatively, he could hope that his team would sell his rights to another team or trade him. This situation was challenged in 1972 by the Curt Flood and Andy Messersmith cases. As a result of these cases, baseball players obtained the property rights to their own services, but only after they have played in the major leagues for six years. Under this system, players who have accumulated six years of service in "the majors", and whose contracts have expired, can declare themselves free-agents and negotiate with any team that is interested.

The first few years of free-agency were tumultuous, characterized by bidding wars for superstars. The then huge contract signed by Catfish Hunter made headlines and it appeared, at least for a while, that the players were becoming successful at capturing more of the rents available. By the 1980's team owners had become alarmed by the increases in salaries brought about by this new free-agent system; a 1986 suit alleging collusion on the part of the teams owners was won by the players. The players asserted that instead of bidding against each other for the services of free agents, the teams had agreed not to bid for the players of any team except their own. The arbitrator in the Kirk Gibson case

awarded damages to the players for the teams' refusal to deal and the 1987 free–agent market is now being contested as containing facilitating practices (the voluntary reporting of bids) which allow teams to keep salaries artificially low.

This history suggests that both sides of the industry would like a new mechanism to allocate free agents. The teams would like one that prevents the bidding wars they feel characterize the current system while the players would like one that is less prone to collusion. This dissatisfaction led us to investigate three distinctly different mechanisms which might be used in the baseball industry. One, the current free agency system (CFA), presents a laboratory version of what we feel are the salient characteristics of the free agent system now in place in the major leagues. The next, a Complete Information English Auction (CIEA), incorporates an information modification of the CFA which the team owners instituted on a voluntary basis in 1987 as a possible solution to what they felt were drawbacks in the current free–agency system. Finally, we investigate a Simultaneous Mechanism (SM) which is a generalization of the Walrasian Mechanism of Demange and Gale (1985) and which uses the algorithm of Leonard (1983) to make its calculations. Let us explain these three mechanisms in turn.

2.1: Mechanism Types

Free Agency (CFA)

The current free agency system (CFA) can be described as follows. By a given date all eligible players declare whether they are free agents or not. After that date any team is free to call any player and vice versa. The content of these negotiations is private information and cannot be verified. At any time a player is free to accept the latest offer made to him by any team; when he does, his participation in the market is over. Negotiations continue until either all players have agreed to a contract, or until time runs out. Payoffs are defined according to the terms of the contracts and whether or not a contract has been made.

Thus the current free agent system constitutes a partial information sequential mechanism since information about the bids made by teams for players is not available while the mechanism is being employed.

Complete Information English Auction (CIEA)

Since the informational asymmetry existing in the current free agent system can be expected to give an undue advantage to players, one may think of modifying the mechanism so that at any point in time all bids made by any team to any player are available for inspection by everyone. Such a system might be organized as follows: Players and teams sit by computer terminals which contain screens indicating the latest bids by all teams for all players. When a team wishes to bid it enters its bid into its terminal. Bids can be changed. When a player wishes to accept a bid, he enters its acceptance and his participation in the market is over. Bidding continues until all players have made a contract or until time runs out. Clearly such a mechanism is of the full information sequential variety since all bids made are common knowledge to all participants.

Simultaneous Mechanisms (SM)

A Simultaneous Mechanism might have the following description: On a given day all teams and players submit bids to a central computer. The bids submitted by the teams would represent the maximum willingness–to–pay that any team has for any player. Hence each team enters a vector of bids, one bid for each player. The bids submitted by the players would represent their reservation prices, namely, the minimum price they require in order to play on any given team. Once these bids are submitted the computer would treat them as if they were the truthful values and costs of the teams and players. It would then match players and teams so as to maximize the sum of the surpluses generated by any such matching. In addition to matching the players and the teams, the computer would also indicate a range in which the salary of the player must be set. Teams and players would then negotiate their salaries within these ranges. Teams and players who fail to

come to a negotiated agreement would be sent to arbitration. Teams and players who fail to make a match would remain unmatched.

The motivation for this type of mechanism comes from the matching literature especially its earliest concern with the "marriage problem". Hence before we explain our experiments and their results, let us pause and quickly summarize the relevant aspects of this literature.

2.2: The Marriage Problem and Matching

Consider a set of men M and a set of women W. The men have complete binary preferences over both the women and the possibility of being unmatched as do the women over the men. The "marriage problem" is to find a way to arrange monogamous marriages between the men and women so that the final outcome is stable. An outcome for the problem is a matching in which each man or woman is either matched with at most one member of the opposite sex or left to be a bachelor or bachelorette. In this context, an outcome of the marriage problem is individually rational if it gives each person at least as much utility as he/she would have if left unmatched. An outcome is stable if it is individually rational and no man and woman can increase their utility by rejecting the person they were matched with and forming a match with each other.

Notice the properties of the marriage problem. Preferences are ordinal, no transferable utility exists, and matching is one-to-one. In this context Gale and Shapley (1962) have shown that a non-empty set of stable matches always exists (i.e. the core of this market is non-empty). They present an algorithm for finding the set of stable outcomes. Further Gale and Shapley (1962) have shown that among the set of stable outcomes there is one (the M-optimal outcome) that is unanimously best for all men and one (the W-optimal outcome) that is unanimously best for all women. More interesting is that fact, as Knuth (1976) has shown that the outcome that is M-optimal is the worst outcome for all women, while the opposite is true for the W-optimal outcome.

In light of the recent work on incentive compatibility, it is not surprising that there does not exist a matching mechanism that gives both sides of the market the incentive to truthfully reveal their true preferences (i.e. truth telling is not a dominant strategy for all agents in the non-cooperative game defined by any matching mechanism). See Roth (1982). In that same paper, Roth has established that any mechanism which yields the M-optimal (W-optimal) outcome defines truth-telling as a dominant strategy for men (women). Hence we can get one side of the market to reveal truthfully.

Demange and Gale (1985) and Leonard (1983) have extended these results to situations in which preferences can be represented by continuous utility functions for which a medium of exchange exists with which to make side payments. Clearly such a generalization is needed if matching algorithms are to be applied to markets where people contract for dollars. The mechanism they use is quite simple. Men and women (teams and players) submit bids indicating the maximum (minimum) they would be willing to pay (must be paid) to be matched with any given players (team). This information is then taken and used to solve for that vector of competitive or Walrasian prices which is element-by-element the minimum. Such a minimum set of prices determines the M-optimal (W-worst) outcome for the market. [Shapley and Shubik (1972) established that such a set of prices exists and that the core of this market is non-empty]. If such a mechanism is used, then, as in the conventional marriage problem, it is a dominant strategy for the men to submit truthful willingness to pay for the women.

To give a flavor of this mechanism we review an example described by Leonard (1983). The example deals with the problem of matching people with objects. Consider the following pair of matrices.

Matrix 1
Individual Preferences

	Individual 1	Individual 2
Object 1	12	11
Object 2	7	4

Matrix 2
Object Preferences

	Object 1	Object 2
Individual 1	0	0
Individual 2	0	0

In this example there are two people and two objects. The people have preferences over the objects as indicated by the numbers in Matrix 1 which shows the maximum any individual would be willing to pay to be matched with either of the two objects. An individual's payoff under the mechanism is the difference between how much he values an object and the price he pays for it. The objects, being inanimate, do not care with whom they are matched. Hence, we have placed zeros in Matrix 2. The value-maximizing match is clearly the one in which individual 1 receives object 2 while individual 2 receives object 1. The surplus generated is 18 which is greater than that generated by the only other possible match. Denote the price of object i as v_i, i = 1,2. For any vector $v = (v_1,v_2)$ in the set of competitive equilibrium price vectors sustaining this match, it must be true that

$12 - v_1 \leq 7 - v_2$

and

$11 - v_2 \geq 4 - v_2$ or

$7 \geq v_1 - v_2 \geq 5.$

Also, since individual rationality forbids a person from paying more than his value for an object we have $v_1 \leq 11$ and $v_2 \leq 7$. These constraints define the shaded area in the diagram below.

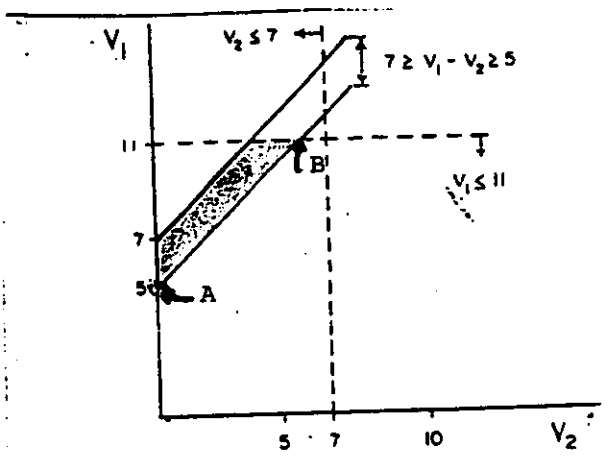


Figure from Leonard (1983) p. 468

Since each individual's payoff is monotonically decreasing in the price he has to pay, we see that individuals are best off at the vector labelled A in the diagram since that vector is price-by-price lower than any other. Vector B is just the opposite. Leonard (1983) demonstrates that if the minimum price vector, A, is chosen then individuals have no incentive to misrepresent their preferences. In addition, he presents a pair of dual linear programming problems which solve for the optimal matches and the minimal prices, respectively. They appear as follows,

Primal Problem I

$$\text{Max} \sum x_{ij}(b_{ij})$$

s.t.

$$\sum_j x_{ij} \leq 1,$$

$$\sum_i x_{ji} \leq 1,$$

where

x_{ij} is the intensity with which we match individual i and object j,

b_{ij} is the bid entered by individual i for object j (objects are assumed to enter zero bids for all individuals),

Dual Problem II

$$\text{Min } \sum_j(p_j)$$

s.t.

$$M_i + p_j \geq b_{ji},$$

$$p_j \geq 0,$$

$$\sum_i M_i + \sum_j(p_j) = V.$$

where

M_i is a fee that must be paid by individual i to participate in the market,

p_j is the price for object j and,

V is the optimal value of the primal problem .

Note that while p_j is the price attached to object j, M_i is a fee that i must pay in order to participate in the market, no matter who he or she is matched with. Hence, changes in M_i have no incentive effects but merely shift the surplus between the individual and the object. When M_i is set at 0, all surplus in a match accrues to the individual, when it is set equal to $b_{ji} - p_j$, all surplus accrues to the objects.

In the markets we are interested in, of course, we care about matching individuals (or teams) with other individuals (or players). Hence we could generalize this Leonard algorithm by allowing Matrix 2 to have non-zero entries c_{ji} indicating the minimum salary that each player would demand in order to be matched with a given team. Hence, our inanimate objects are now replaced by people who have preferences. This would generate the pair of dual problems Ia and IIa:

Primal Problem Ia

$$\text{Max } \sum x_{ij}(b_{ij} - c_{ji})$$

s.t.

$$\sum_j x_{ij} \leq 1,$$

$$\sum_i x_{ji} \leq 1,$$

Dual Problem IIa

$$\text{Min } \sum_{ij}(p_j - c_{ji})$$

s.t.

$$M_i + (p_j - c_{ji}) \geq (b_{ji} - c_{ji}),$$

$$p_j \geq c_{ji},$$

$$\sum_i M_i + \sum_{ij}(p_j - c_{ji}) = V.$$

In these problems all notation is as we described above except

c_{ji} is the bid entered by player j for team i,

If programs Ia and IIa are used to process the bids entered by the players and teams, and if Mi = 0 so that the price of the match is the lowest competitive price supporting this outcome (i.e. determines the Team-optimal core imputation) then it is still a dominant strategy for the teams to report truthfully. Such is not the case for the players, however, since obviously their bids will influence the price of the matches made.

On a practical level, there are three immediate objections to this mechanism. First, players may object that it is not fair to them since it determines that price which is best for teams given any set of messages or bids. Another equally plausible mechanism would be one that yielded the highest set of prices or in which the imputations of the players were as high as possible (i.e., $M_i = b_{ji} - p_j$) -- choosing to give the surplus to the teams is arbitrary. Second, the baseball industry has a history of bargaining for salaries; the participants may not be willing to accept salaries and team assignments that are prescribed by some mathematical maximization problem and its dual. Finally, because there is no role for bargaining here, the mechanism has substantially cut down on the role of the sports agent. Eliminating their profits may ultimately lead to the rejection of this mechanism as politically unfeasible.

To answer these objections we, instead, tested a modified version of this mechanism in our experiments. In our version, subjects playing the role of teams (which we called U-type subjects) and subjects playing the role of players (which we called S-type subjects) submit their bids just as we described above. Using this information programs Ia and IIa determine the optimal matches and tell each pair of subjects who are successfully matched the range in which their salary must be negotiated. This range is defined by program IIa and for each pair it falls in the interval $[v_{ji}, v_{ji} + b_{ji} - p_j]$. Note however, that this range is simply the range defined by letting M_i vary from its minimum value of 0 to its maximum of $b_{ji} - p_j$.[1]

This mechanism preserves bargaining as well as a role for the sports agent. The drawback, of course, is that this mechanism (as well as the mechanism that uses the unrestricted program IIa) does not make it a dominant strategy for any subject to tell the truth so we have lost even the partial incentive compatibility properties discussed before. Still, it is neither a necessary or sufficient condition that a mechanism be incentive compatible. Many mechanisms that lack this property perform quite well in efficiency terms. In fact, even inefficient mechanisms may be popular with the people who use them for a variety of political and sociological reasons.

2.3: Some Preliminary Results

Our experiments were aimed at investigating three simple questions:

1) Which type of mechanism performed the best-- i.e. which was better able to capture a greater fraction of the potentially available gains from trade and which was able to produce the most number of optimal matches?

---

[1] Due to a minor programming error some of the prices reported to the subjects differed from those dictated by programs Ia and IIa. While 73% of the prices reported were those of the programs the remaining 27% were not. Still, the median change amongst those that differed was only 5 cents and such a change we consider undetectable by the subjects.

2) Under which mechanism were prices the highest?

3) Which mechanism generated the highest profits for the teams and which were most beneficial for the players?

On the basis of the experiments performed we have the following conclusions to offer:

1) Except for its tendency to yield no matches when extreme bids are entered, the SM mechanism employed in our experiments demonstrated good performance characteristics, ones that were on par with the CFA and CIEA mechanisms. For example, while 14 out of a possible 180 potential matching situations (7.7%) led to no matches, for the remaining 166 the mechanism was able to capture 97% of the available gains from trade. It did this by determining optimal matches for 146 of the remaining matches. While average efficiencies were better under the CFA mechanism where 94.8% of the potentially available gains from trade were captured as opposed to 89.4% for SM, the CFA mechanism generated a far greater number of mismatches (31 out of 150) than did SM (which had only 20 out of 180). Further, it appears that the frequency of no matches under SM can be accounted for by the "extreme" bids entered by these subjects which misrepresent their true values and costs by amounts ranging from 56% to over 400%. The CIEA mechanism performed in a manner equivalent to the SM mechanism. It had the greatest fraction of no matches (14 out of 150 potential matches or 9.3%). In addition, when it succeeded in matching subjects it failed to make the optimal match in 14 out of 136 instances. Overall (including the no match data) it was able to capture 88.3% of the available gains from trade and 97.4% of the gains available when it was successful in matching subjects.

2) Prices tended to be highest under the CFA mechanism with the SM mechanism being second and the CIEA mechanism yielding the lowest prices of all. In terms of the actual prices formed, the CFA mechanism yielded an average price of $2.65 while the SM

mechanism determined an average price of $2.35 and the CIEA an average price of $2.20. These differences proved to be statistically significant.

3) Since prices were lower in CIEA than in the SM and CFA experiments (in that order), one would expect that U-type (buyer) payoffs would be ranked in the same order (CIEA, SM, and then CFA), while the S-type (seller) payoffs' ranking would be opposite. This, in fact, was the case. Under CFA, average realized payoffs equalled $1.87 and $1.94 per round for U and S-types respectively, as compared to $2.00 and $1.72 for SM and $2.07 and $1.45 for CIEA.

In short, by looking at gross summary statistics it would appear that the efficiency properties of all mechanisms were quite good with the CFA mechanism doing the best (in a statistically insignificant manner). In addition, while CIEA yielded the highest payoffs for U-type subjects, CFA was distinctly more advantageous for S-types.

In the remainder of this report we fully describe the experiments that were performed (Section 2) to investigate the properties of these three mechanisms and then present a full description of the results (Section 3). In Section 4 we discuss the results of some statistical tests performed on the data while in Section 5 we present an analysis of what we think the implications of this study are for the design and implementation of a baseball player allocation system.

Section 3: The Experiments and Experimental Design

Three sets of experiments were conducted each aimed at replicating the salient features of a different allocation mechanism. In the Appendix we present the instructions given to subjects in each experiment. Since all of the experiments shared some common features, let us explain these first before we proceed to a description of the separate experiments.

The objective of the subjects in all three experiments was to try to match themselves with another subject in the experiment and determine a price for that match. While the manner in which this was done changed from experiment to experiment, the preferences induced on the subjects were identical. This allowed us to impute any differences in behavior and performance to the institutional rule or mechanism used in the experiment. In all of the main experiments reported here [2] subjects were randomly assigned to be either one of two types called in the instructions U-types or S-types. The instructions also informed them that they could be matched with <u>at most</u> one subject of the opposite type and that their payoffs would depend upon whom they were matched with and the price determined for the match. To induce preferences on the subjects, U-types were given a schedule informing them of the amount of money they would be paid if they were matched with any S-type subject denoted as S_1, S_2, and S_3. These three values were similar in that it was always true that each U-type valued one S-type at \$5, one at \$4.5 and one at \$4. However, no U-type subject knew the preferences of anyone else but himself.

To induce preferences on the subjects, S-types were given a schedule informing them of the amount of money they would have to pay at the end of the experiment if they were matched with any U-type subject denoted as U_1,U_2, and U_3. These three values were similar in that it was always true that each S-type always valued one U-type at \$.5, one at \$1 and one at \$2.[3] However, no S-type subject knew the preferences of anyone else but himself. In each round of the experiment we would change these schedules but these changes merely constituted a permutation of the indices attached to the following pair of matrices:

---

[2] Some subsidiary experiments were performed as pilot experiments and while we will not refer to them in the main body of the text of this report, some reference to them will be made in footnotes.

[3] In the SM experiment all values and costs for U-types and S-types were multiplied by a factor of 10. We will discuss the reason for this later.

Matrix 3: U-Type Preferences

	U1	U2	U3
S1	4.5	4	5
S2	5	4.5	4
S3	4	5	4.5

Matrix 4: S-Type Preferences

	S1	S2	S3
U1	.5	2	1
U2	1	.5	2
U3	2	1	.5

These matrices define all of the information known to the experimenter in each round of the experiment. Looking down each column we see the value (Matrix 3) or cost (Matrix 4) of each U-type (S-type) for subjects of the opposite type. Each subject knew only the column in the matrix relevant to himself but knew that U-types had values of either \$5, \$4.5, and \$4 while S-Types had values of either \$.5, \$1, or \$2. Note that with these parameters profitable matches could be formed between any S-type subject and any U-type subject and that the difference between the surplus generated by optimal matches and sub-optimal matches was not great. This, we expected would lead to a fair amount of competition between the subjects.

As we see, the optimal (surplus maximizing) set of trades occurs when S-type subjects with a cost of \$.5 were matched with U-type subjects with a cost of \$4.5. All of these matches generated a surplus (sum of the consumers plus producers surplus) of \$4

while any other match generated a surplus of only $3. Hence, in every round of the experiment the set of optimal matches remained unique although because we permuted the indices it was not always true that U_1 was matched with S_1, U_2 with S_2, and U_3 with S_3.

Notice that the optimal matching does not allocate U-types their first choice but rather their second. This was done to prevent the first-ranked alternative for the U-types from becoming salient and biasing the process toward an optimal set of matches. In pilot experiments others preferences were investigated as well. Holding these preferences constant across experiments allows us to impute the differences between experiments to the different sets of rules existing in each one and not to value or cost changes. .

3.1: The CFA Experiment

The CFA experiment was quite simple. Students were placed in offices of economics professors in the Department of Economics at New York University. On the desk where they sat was a telephone, a list of telephone numbers and a set of ten envelopes one for each round of the experiment. If a subject was a U-type subject, the telephone numbers given him or her were those of the S-types. The opposite was true for S-type subjects. Each round began with subjects opening one envelope. In this envelope was a piece of paper indicating the subject's preference schedules for that period. After these envelopes were opened and the information recorded on worksheets, the subjects had 5 minutes within which time they could call subjects of the opposite type and try to negotiate a match and a match price. If such a contract was formed, its existence was announced publicly and those subjects were out of the market for the remainder of that round. If a U-type subject was successful in making a match within the 5 minute time limit, his or her payoff was equal to the difference between the value of the S-type subject they were matched with and the price of that match. For S-type subjects who were successfully matched, the payoff was equal to the difference between the price of the match and the cost of the U-

type subject they were matched with as was indicated on their schedule. If a subject failed to be matched his or her payoff was zero for that round. A subject's final payoff equalled the sum of his or her payoffs over the entire 10 rounds of the experiment.

3.2: The CIEA Experiment

The CIEA experiment was conducted as follows: Subjects were seated in a class room with S−types in the first row and U−types in the rear. At their seats were a stack of ten envelopes as well as a small chalkboard upon which they would write messages. At the start of each round the subjects would again open their envelopes and inspect their preferences for that round. They would then be given 5 minutes to complete their contracts. This was done as follows: In the front of the room was a blackboard with the following table on it.

S_1	S_2	S_3	Contracts
U_1 U_2 U_3	U_1 U_2 U_3	U_1 U_2 U_3	

When the experimental administrator says "begin", the U−type subjects could enter a bid for any player of the S−type they wanted. This would be done by writing the bid on their chalkboard and raising it above their head. The experimental administrator stationed in the front of the room would then write the bid under the S−type subjects column. For example, if subject U_2 wanted to bid \$1 for S_1, he or she would only have to write S_1-1 on their chalkboard. This bid would then be placed in the U_2 column under the heading for subject S_1. As bids are made they are recorded in the appropriate places on the board. The last bid made by a U−type subject for an S−type subject was the only one currently available and remained active until either accepted or until the U−type had one of his other bids accepted. S−type subjects could not make counter offers but could accept bids by writing the word "accept" and the identity of the subject whose bid was being accepted on their chalkboard. When they did so, a contract was made and the experimental

administrator notified everyone by writing who formed it and its price on the blackboard. Note that the experiment was conducted in total silence and hence avoided the hysteria of oral auctions. Payoffs were calculated in an identical manner as discussed in the CFA experiment. Note, however, that in this experiment all bids made for all S-types are common knowledge.

3.3: The SM Experiment

In the SM experiment subjects were seated at computer terminals. At the beginning of each round their preference schedules were flashed on the screen. They were then prompted by the computer to enter a vector of bids, one for each subject of the opposite type. This information from all subjects was entered into the main file server of the network where programs Ia and IIa were solved.

Once the optimal matches are determined, subjects are matched and told that they have 5 minutes to determine a price for their match. The price can be anything in the closed interval $[p_j, p_j + M_i]$. Because price setting in this mechanism requires some bargaining, we did not want to disrupt the experiment after each round and allow subjects to bargain. Hence we multiplied the payoffs in each round by 10 and told the subjects that one round would be randomly chosen at the end of the experiment as the round that would count. The matches and prices determined in this round would, by themselves, define payoffs for each of the S and U-type subjects[4]

3.4: Experimental Design

Our experimental design is described in Table 2.1:

Table 2.1: Experimental Design

Experiment	Number of Groups	Preferences	Number of Rounds	Number of Subjects
1) CFA	5	Matrices 1&2	10	30

[4]This is why we multiplied all payoffs here by ten in order to preserve an equivalent expected payoff between these subjects and those of the other experiments.

2) CIEA	5	Matrices 1&2	10	30
3) SM	6	Matrices 1&2	10	30

We conducted three experiments. In two, CFA and CIEA, we had 5 independent groups each containing three S-type and three U-type subjects; each group performed the experiment for 10 rounds. For the SM experiment we had 6 independent groups. Hence all together we had 96 subjects involved in these experiments.[5] As can be seen, since all experiments are identical except for the allocating rule, they furnish us with a ceteris paribus test for the influence of the mechanisms themselves, holding preferences constant.

3.5: Data Set

Given our experimental design, our experiment can be expected to yield the following data. In each round of each experiment there is a potential for at most 3 matches. Hence in experiments like CFA and CIEA where we have 5 groups of subjects, there are at most 15 potential matches per round and 150 potential matches over the course of the 10 round experiment. For SM, since there are 6 groups and 10 rounds, we generate a total of 18 potential matches per round and 180 over the 10 rounds of the experiment. Attached to each match made is a price, and payoffs for each U-type and S-type subject as well as an efficiency for that match which we measure by the fraction of the gains from trade available from an optimal match that was captured by the match actually made. For example, from matrices 1 and 2 above we know that when an optimal match is made it generates a surplus of \$4[6] as measured by the excess of the U-type subject's value over the S-type subject's cost. Given our data any sub-optimal match produces an excess of \$3 while a no-match produces an excess of 0. Hence, the efficiency of an optimal match is (\$4/\$4)x100%, while that of a sub-optimal match is (\$3/\$4)x100% and a no-match is (0/\$4)x100%. In the CFA and CIEA experiments we had a price, payoff, and efficiency

[5] This does not include a set of pilot experiments we performed as well.

[6] This surplus is 40 in the SM experiment where all values and costs are multiplied by 10.

actually formed whenever a match was made. This lead to 150 and 136 prices, payoffs and efficiencies made over the course of each of the CFA and CIEA experiments respectively (there were 14 no-matches in the CIEA experiment). In the SM experiment we chose one and only one round in which to actually have a price negotiated in each experiment. Hence we had only 17 prices actually formed (there could have been 18 but in one of the rounds selected there was one no-match in one experiment). Despite this fact, we still had 166 efficiencies since they depend only on the matches made by the mechanism (there were 14 no matches in SM). For the SM mechanism, in addition to investigating the set of 17 prices that we actually negotiated, we constructed two hypothetical prices for each match. In one we assume that when a match is made the subjects would split the fee M_i over which they bargain. This would lead to a price at the mid-point of the interval $[p_j, p_j + M_i]$. We'll call this the "split-the-difference" price. Our other hypothetical price is merely the price p_j or the "match price". These two prices, of course, yield two different payoff measures.

Section 4: Results

In terms of broad descriptive statistics, Table 4.1 describes the results of our experiments. Let us interpret this table by investigating the efficiencies, prices and payoffs generated by our experiments:

TABLE 4.1

CFA–SM–CIEA EXPERIMENTS: SUMMARY OF RESULTS

STATISTIC	CFA	SM^I	SM^E	$CIEA^I$	$CIEA^E$
A. EFFICIENCIES					
Surplus Measure	94.8%	89.4%	97.0%	88.3%	97.4%
Numbers Measure	79.3%	81.1%	87.9%	81.3%	89.7%
B. PRICES (per round)					
Average Negotiated Price	$2.65	$2.22	$2.35	$2.00	$2.21
Avg. Split–the–difference Price	–	$1.92	$2.09	–	–
Mode Negotiated Price	$2.50	$2.20	$2.20	$2.50	$2.50
Mode Split–the–difference Price	–	$2.00	$2.00	–	–
C. PAYOFFS (per round)					
1) S–types (Sellers)					
Negotiated Price	$1.94	$1.72	$1.82	$1.45	$1.61
Split–the–difference Price	–	$1.36	$1.48	–	–
2) U–types (Buyers)					
Negotiated Price	$1.87	$2.00	$2.12	$2.07	$2.29
Split–the–difference Price	–	$2.21	$2.39	–	–

KEY:

SM^I: SM including "no match" outcomes
SM^E: SM excluding "no match" outcomes
$CIEA^I$: CIEA including "no match" outcomes
$CIEA^E$: CIEA excluding "no match" outcomes

4.1: Efficiencies

Table 4.1 provides two measures of efficiency. One has been described above and is called the "surplus measure" since it measures the fraction of the available surplus or rents captured by our subjects. The other measure is called the "numbers measure" and measures the fraction of the total number of potential matches that were optimal. Let us look at our experiments one at a time.

4.1a):The SM Experiment

In the SM experiment, out of 180 potential matches, there were 14 (7.7%) "no-matches" 20 (11.1%) sub-optimal matches and hence 146 (81.1%) optimal matches. By definition this yielded a numbers efficiency of 81.1%. In terms of surplus efficiency, SM was successful in capturing 89.4% of the potentially available gains from trade or surplus including the zero efficiencies generated by the 14 no matches. If we exclude these no matches and only look at the fraction of the surplus captured when matches were actually made, we see that SM was successful in capturing 97% of the surplus.

4.1b):The CFA Experiment

In the CFA experiment, out of 150 potential matches, there were no no-matches (0%) and 31 sub-optimal matches (20.6%). 119 (79.3%) of the potentially available matches were optimal yielding a numbers efficiency of 79.3%. In terms of surplus efficiency, CFA was successful in capturing 94.8% of the potentially available surplus.

4.1c):The CIEA Experiment

In the CIEA experiment, out of 150 potential matches, there were 14 no-matches (9.3%) and 14 sub-optimal matches (9.3%). 122 (81.3%) of the potentially available matches were optimal yielding a numbers efficiency of 81.3%. In terms of surplus efficiency, CIEA was successful in capturing 88.3% of the potentially available gains from trade or surplus including the zero efficiencies generated by the 14 no matches. If we exclude these

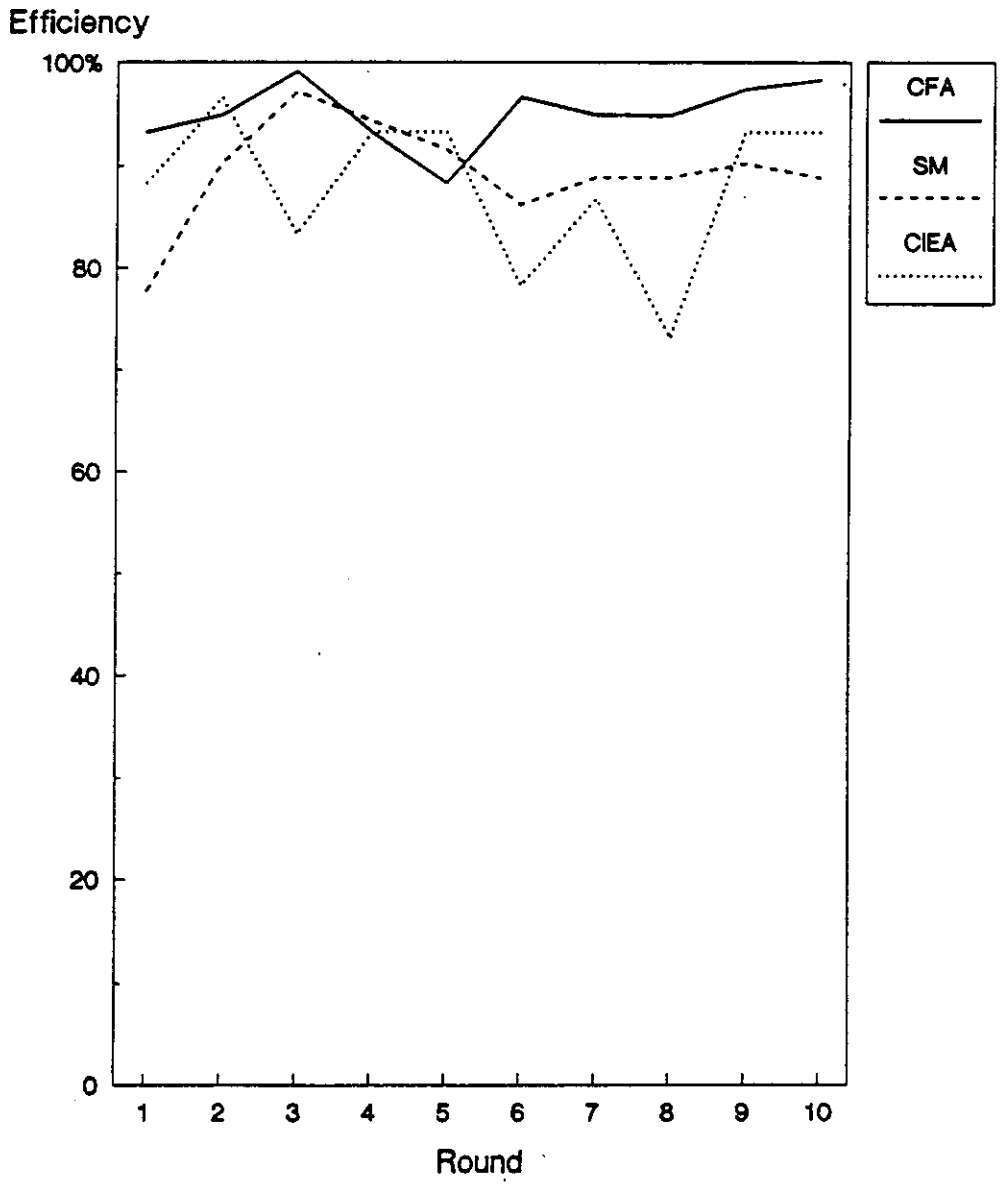
no matches and only look at the fraction of the surplus captured when matches were actually made we see the CIEA was successful in capturing 97.4% of the surplus.

Figures 1, 2 and 3 portray the round by round mean surplus and numbers efficiencies over the ten rounds of the experiment. As we can see in Figure 1, when we include the zero efficiencies generated by no-matches in both the CIEA and SM experiments, the efficiencies of our three mechanism are roughly equivalent with CFA performing best and then SM and finally CIEA. In Figure 2, where we exclude the instances of no-matches, we see that SM and CIEA outperform the CFA mechanism. Hence, on visual inspection of the data, except for its tendency to create no-matches, the SM mechanism has performance qualities comparable to those of both CFA and CIEA. In Figure 3 we see the numbers efficiencies which again demonstrate no major differences in efficiencies between the three mechanisms.

To investigate these observations we performed two sets of tests. First we ran a round-by-round Mann-Whitney U test on each pair of experiments to see whether there were significant differences in the mean efficiencies between these mechanisms taken pairwise. Since within an experiment observations are not independent, we created a sample of group means round by round by averaging the efficiencies generated by matches within any group and using these group means as a sample. We also performed this test by pooling all of these observations over the ten rounds of the experiment.

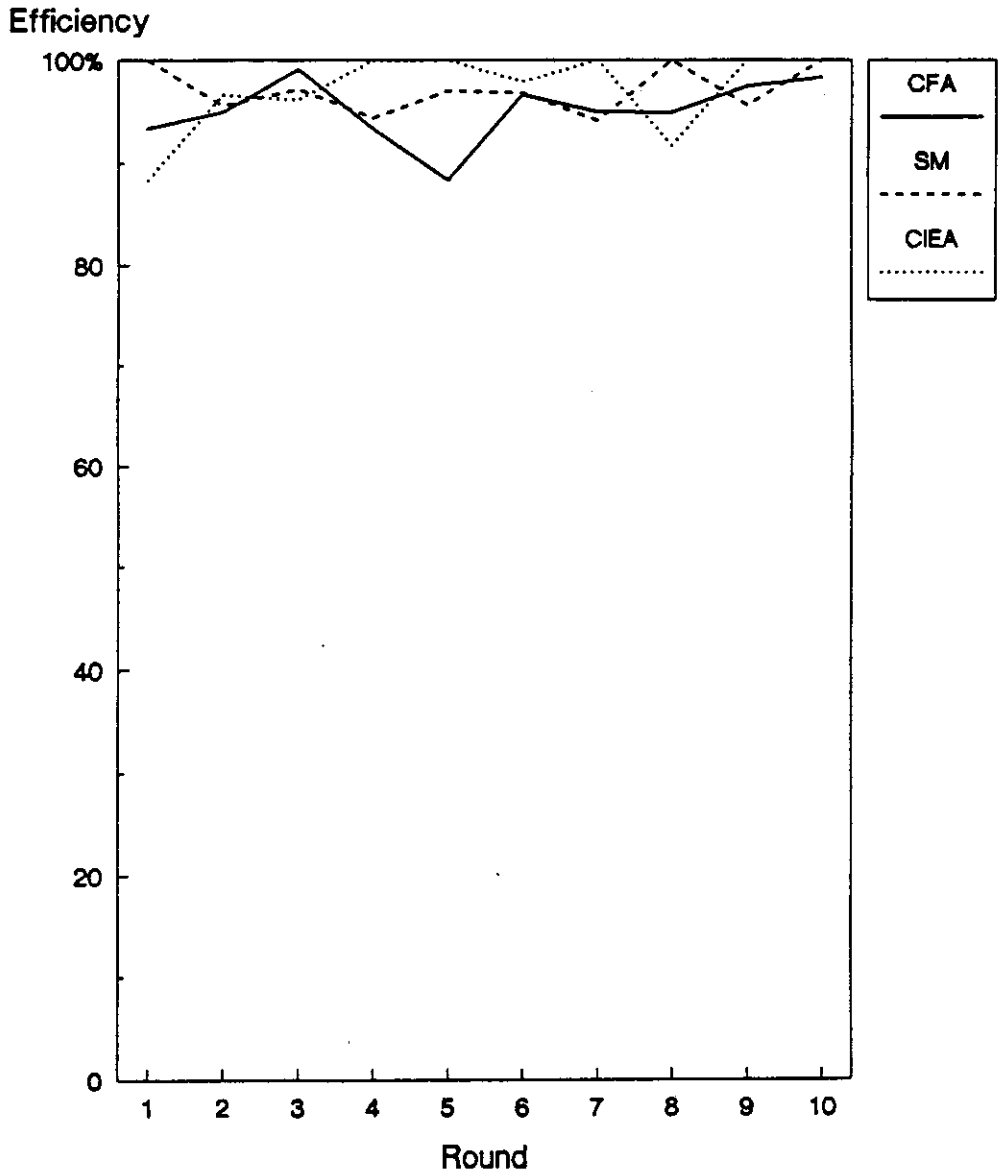
Table 4.2 presents the results of our Mann-Whitney U tests. As we can see, no general patterns appear when we look at the statistical significance of our general impressions.

Figure 1: CFA-SM-CIEA Experiments
Round By Round Surplus Efficiency
including no matches



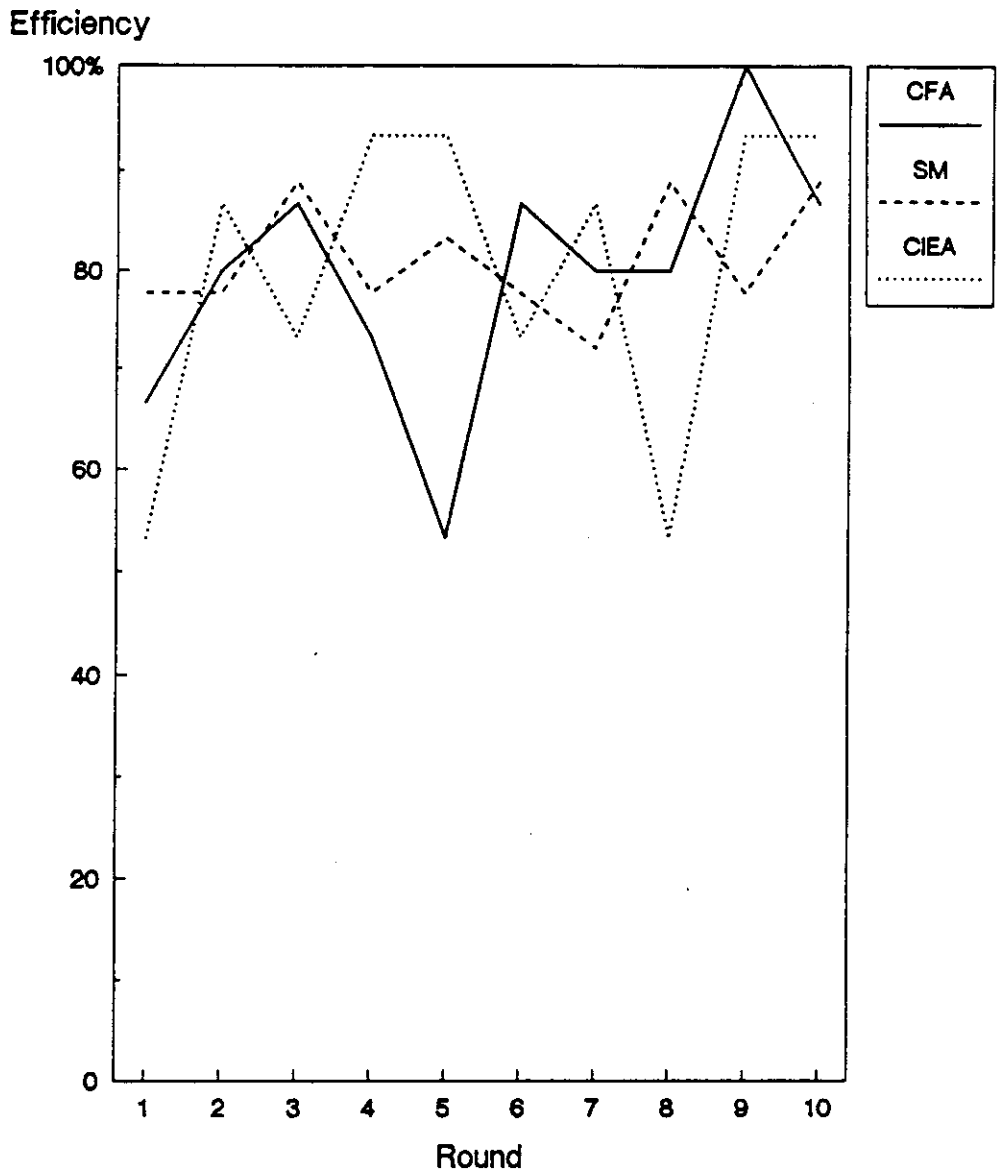
Efficiency is defined as the sum of actual payoffs as a percentage of the total available gains from matching.

Figure 2: CFA-SM-CIEA Experiments
Round By Round Surplus Efficiency
excluding no matches



Efficiency is defined as the sum of actual payoffs as a percentage of the total available gains from matching.

Figure 3: CFA-SM-CIEA Experiments
Mean Numbers Efficiency Round by Round



22c

Table 4.2: Efficiencies
Surplus Efficiencies

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.04	1.0	2.09
	(.148)	(.157)	(.017) *
2	0	.091	.456
	(.50)	(.463)	(.324)
3	0	.091	.091
	(.50)	(.463)	(.463)
4	.626	.091	.456
	(.265)	(.463)	(.324)
5	1.46	1.18	.456
	(.07) **	(.117)	(.324)
6	.00	.091	.456
	(.50)	(.463)	(.324)
7	.00	.091	.456
	(.50)	(.463)	(.324)
8	.122	1.00	.533
	(.451)	(.157)	(.297)
9	.835	.091	.821
	(.201)	(.463)	(.205)
10	1.25	.821	.639
	(.105)	(.205)	(.261)
Pooled data	1.29	1.20	.216
	(.091)**	(.113)	(.414)

Table 4.2: (continued)
Numbers Efficiency

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	.417	1.0	1.55
	(.338)	(.157)	(.063) **
2	1.46	1.55	.273
	(.071) **	(.060) **	(.392)
3	1.67	1.73	.091
	(.047) **	(.047) **	(.463)
4	1.04	.091	1.36
	(.148)	(.463)	(.085) **
5	1.46	1.36	.456
	(.07) **	(.085) **	(.324)
6	.00	.456	.639
	(.50)	(.324)	(.261)
7	.835	.091	1.18
	(.201)	(.463)	(.117)
8	.367	.456	1.17
	(.356)	(.324)	(.120)
9	.00	.821	.821
	(.500)	(.205)	(.205)
10	.417	.456	.091
	(.338)	(.324)	(.463)
Pooled data	.064	.549	.606
	(.473)	(.291)	(.272)

Note: The entry in each cell can be read as follows:
{ z-score
(one-tailed
probability)

** means significant at the 10% level or less

In terms of surplus efficiencies, there seems to be relatively more statistically significant differences between the surplus efficiencies generated by the CFA and CIEA experiments (they differed in three of the ten rounds of the experiment and the pooled data showed a difference here at the 10% level of significance) than existed between the other two comparisons, yet this is not enough to warrant the claim that these mechanisms performed differently.

4.1d: No-Match Behavior

Since the efficiency of the SM mechanism was dramatically affected by the existence of no-matches, it is of interest to discover how much of a deviation from one's true cost

or value is needed in order to generate such no-matches. Of course if all subjects merely bid their true value and cost in the experiment, then we would always observe 100% efficiencies being generated. The extent to which we observe sub-optimal outcomes is therefore evidence of the extent of misrepresentation on the part of our subjects. To study this misrepresentation behavior in the SM mechanism we present Table 4.3 and Figures 4 and 5. In Table 4.3 we see the mean deviation of bids by U-type and S-type subjects from their truthful bids and costs averaged over all tend rounds of the experiment and conditional on their realized outcomes.

Table 4.3: Misrepresentation of Preferences

U-Type Average Deviations From True Values

Efficient Matches Value			Inefficient Matches Value			No-Matches Value		
50	45	40	50	45	40	50	45	40
15.4	14.8	13.9	11.9	14.3	9.75	28.7	28.4	24.5
30%	32%	34%	24%	31%	24%	57%	63%	61%

S-Type Average Deviation From True Cost

Efficient Matches Value			Inefficient Matches Value			No-Matches Value		
20	10	5	20	10	5	20	10	5
6.52	6.71	5.08	3.70	6.70	11.0	18.3	19.1	20.6
32%	67%	101%	19%	67%	220%	91%	191	412%

Note: The entries in the rows are the average deviations from true costs and values. The percentages are the percentage deviations.

As we can see, there is a discrete difference between the type of misrepresentation that exists in instances that lead to no-trades and that occurring in those instances that lead to trades. For example, while the mean deviation for U-types with a value of $50 for an S-type was $15.4 for those bids leading to optimal matches, it was $28.7 for those bids leading to no-matches. For S-types a similar situation existed. When S-types bid for U-types for whom they had a cost of $20, they tended to raise their bid a average of $6.52

above their cost (they bid on average $26.52) for those bids leading to optimal matches. When their bid led to a no-match, it was typically $18.3 above their cost ($38.3) representing an almost 300% increase. There seemed to be no difference between those bids leading to optimal and those leading to sub-optimal matches. This leads us to think that, despite the substantial number of no matches, the SM mechanism is fairly robust to strategic manipulation in the sense that it took a very large misrepresentation to lead to a no-match outcome. Furthermore, since without no matches the SM mechanism performed extremely well, one might conclude that over time, when such misrepresentations are discovered to be counter-productive, the efficiency of the SM mechanism would increase. We did not run our mechanism long enough to uncover this tendency although we do note that 28% of the no-matches did occur in round 1 of the experiment.

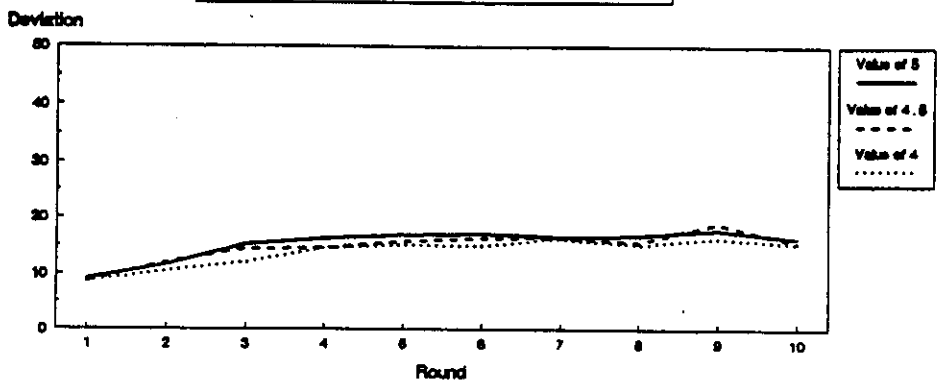
Figures 4 and 5 plot the mean deviation of bids from value (cost) round by round for U and S types. As we see, the U-types exhibited considerably bigger deviations from their true values than did the S-types from their costs. More significantly, perhaps, is the fact that as the experiment progressed the deviations of the U-types seemed to increase. This, we feel, is because the U-type players were capable of discovering the relationship between their bid and the fee M_i that they would eventually be negotiating over. (In fact, the fee M_i was the difference between the price p for their match and their bid.) Hence by lowering their bid, as long as it did not prevent their getting matched, they could lower the range over which the final price would be negotiated.

The pattern of bidding behavior for S-type subjects over ten rounds appears relatively stable, with no significant trend in either direction. The average bid for high-cost matches ($20) declined by 6% from round 1 to 10, never exceeding the first round value; the decline for middle-cost matches ($10) was 8%, also remaining persistently below the first round value. This suggests the presence of a modest learning effect, though the movement of values over all ten rounds is more consistent with stable valuations. It is

Figure 4: SM U-Type Misrepresentation

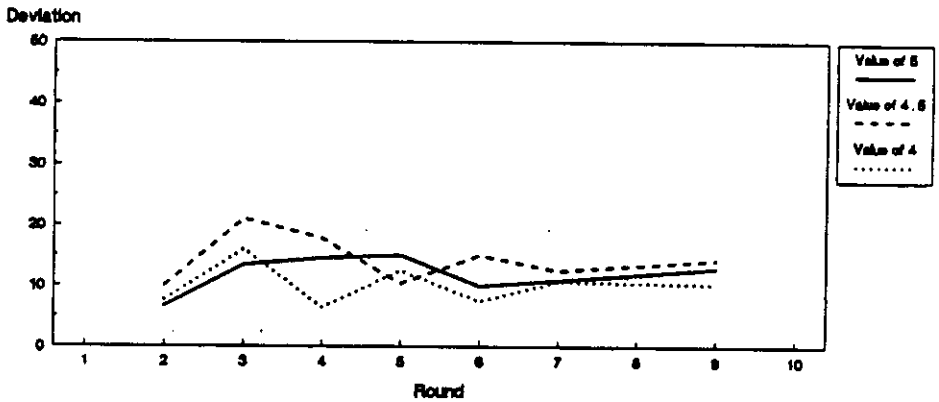
Behavior (Average Deviations) By Round

Optimal Matches



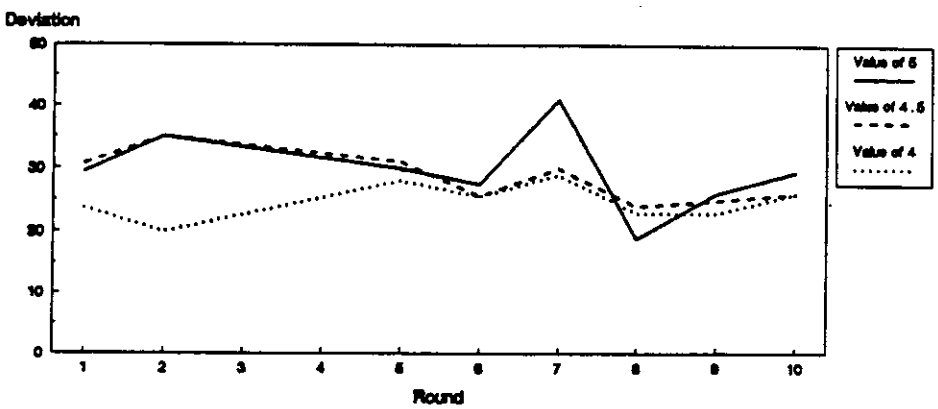
Deviation is defined as the value minus the actual bid averaged across all u-types in each round.

Inefficient Matches



Deviation is defined as the value minus the actual bid averaged across all u-types in each round.

No Matches

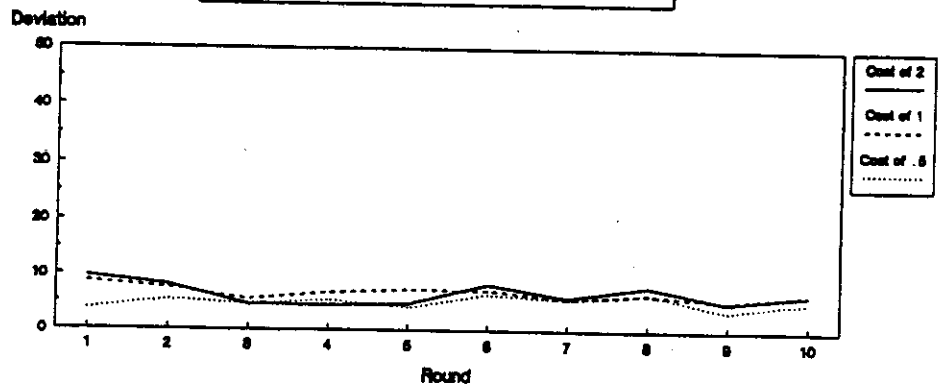


Deviation is defined as the value minus the actual bid averaged across all u-types in each round.

Figure 5: SM S–Type Misrepresentation

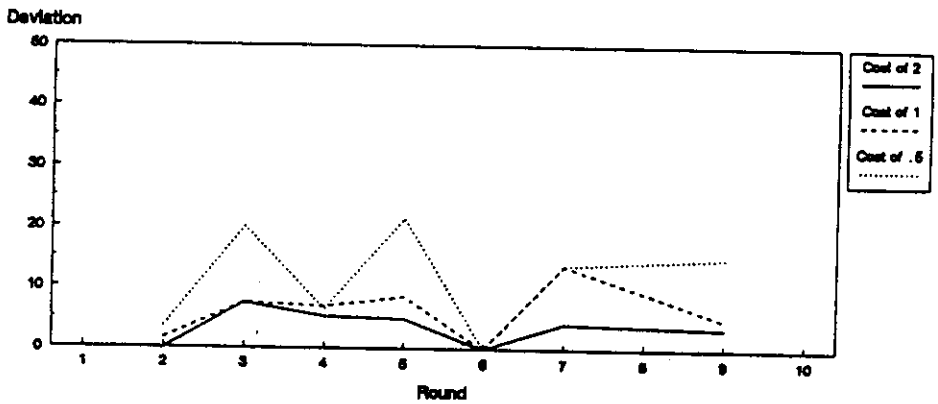
Behavior (Average Deviations) By Round

Optimal Matches



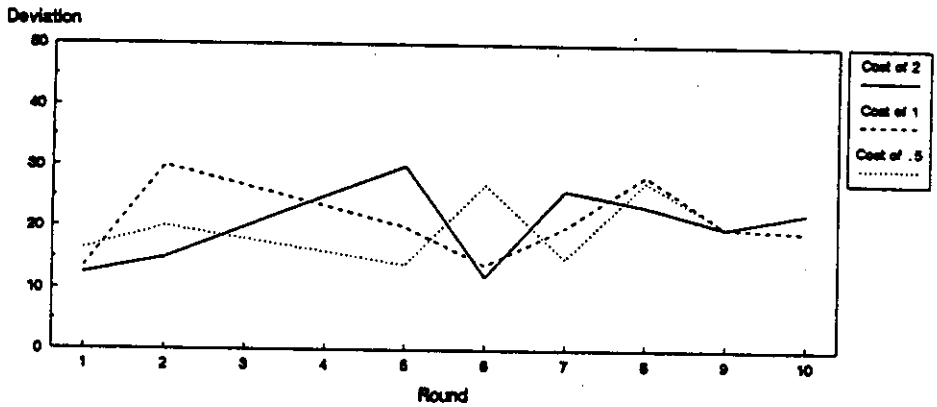
Deviation is defined as the actual bid minus the cost averaged across all e-types in each round.

Inefficient Matches



Deviation is defined as the actual bid minus the cost averaged across all e-types in each round.

No Matches



Deviation is defined as the actual bid minus the cost averaged across all e-types in each round.

interesting that the average bid for lowest-cost matches ($5, the optimal match) rose by 6% from round 1 to 10, dropping below its initial level in only three of ten rounds.

The excess of average S-type bids across rounds over match costs are*:

Cost (C)	Average Bid (AB)	AB - C	% Excess
$20	$27	$7.00	35%
$10	$17.60	$7.60	76%
$5	$11.90	$6.90	138%

*These bids are pooled over all subjects and all rounds regardless of whether they lead to matches or not.

In terms of absolute dollar values, S-Types were quite consistent in demanding an approximately $7.20 premium over actual costs regardless of match type. In percentage terms the premium for the low-cost (optimal) match was substantially higher. In contrast, as we shall see below, U-types, behaved consistently over all possible matches, deviating in their bids from actual values by roughly 35%.

The bidding behavior of U-types showed a pronounced downward trend over the course of ten rounds (upward trend in deviations). The average bid for highest-value matches ($50) dropped by 11% from round 1 to 10, exceeding its initial level only once (in round 2) and declining almost steadily from round to round; the decrease for middle-value matches ($45, the optimal match) was 9%, also remaining persistently below its initial level after the second round. Bids for lowest-value matches ($40) behaved similarly, showing a 16% decline. Here too, the initial bid level was exceeded only once, in the second round. It appears that after an initial testing period (rounds 1 and 2), U-type subjects adopted an aggressive bidding strategy of persistent bid reduction which they implemented successfully as they gained experience with the matching mechanism.

The excess of match values over average bids across rounds are:

Values (V)	Average Bid (AB)	V − AB	% Excess
$50	$33.80	$16.20	32%
$45	$29	$16	35%
$40	$25.60	$14.40	36%

*These bids are pooled over all subjects and all rounds regardless of whether they lead to matches or not.

There is no discernible difference in the way that U−types bid with respect to match types. Certainly, there is nothing to indicate in observed bidding behavior that U−types learned to discriminate between optimal and non−optimal matches. Overall, it is clear that dollar value deviations of U−type bids from valuations strongly exceeded deviations of S−type asks from costs. This differential pattern drove the bargaining process and had a visible impact on match prices and ultimate payoffs.

4.2: Prices

As table 4.1 indicates, prices tended to be highest when the CFA mechanism was used and considerably lower when the SM and CIEA mechanisms were used. The mean price under the CFA mechanism was $2.65 while it was $2.35 for prices actually negotiated in the SM experiment. When we look at what the prices would have been in the SM experiment if we made the assumption that our subjects would "split the difference" and negotiate a price at the midpoint of their bargaining interval, we see that the mean price would have been even lower at $2.09. The CIEA experiment yielded an average price of $2.21.

The same Mann−Whitney U tests were performed on the price data as were performed on the efficiencies data; more definite conclusions can be drawn. For example as Table 3.4 indicates, the CIEA mechanism generated prices which were significantly below those of the CFA and SM mechanisms. When we compare the mean prices formed in any

round by the five groups of subjects each in the CFA and CIEA experiments, we see that in 7 of the 10 rounds there was a statistically significant difference (at the 10% level or below) between the mean price formed in the CFA and CIEA experiments. Similarly, there was a statistically significant difference in 8 of the 10 rounds between SM and CFA mechanisms. In no round was there a significant difference between the prices formed in the CIEA and SM experiments.

Table 4.4: Prices: Mann–Whitney U Tests For Differences in Means Across Experiments

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.25	2.28	1.18
	(.105) **	(.011) *	(.117)
2	.625	.639	.091
	(.265)	(.261)	(.463)
3	.208	1.36	.273
	(.417)	(.085) **	(.392)
4	1.25	1.00	.091
	(.105) **	(.157)	(.463)
5	2.29	2.64	1.18
	(.01) *	(.004) *	(.117)
6	1.46	1.91	.456
	(.07) **	(.027) *	(.324)
7	.83	1.55	.639
	(.20)	(.060) **	(.261)
8	1.34	1.73	.106
	(.089) **	(.041) *	(.457)
9	1.46	2.09	.821
	(.071) **	(.017) *	(.205)
10	1.67	1.73	.453
	(.047) *	(.041) *	(.324)
Pooled data	4.00	5.80	1.48
	(.000) *	(.000) *	(.069) **

Note: The entry in each cell can be read as follows:

{ z–score
(one–tailed
probability)

* means significant at the 5% level or less
** means significant at the 10% level or less

In short, the CFA mechanism did, in fact, determined prices which were significantly higher than those formed by either the SM or CIEA mechanisms, while SM and CIEA were statistically indistinguishable.

Figure 6: SM (Actual/Constant Mean)-CFA-CIEA
Mean Price Per Round

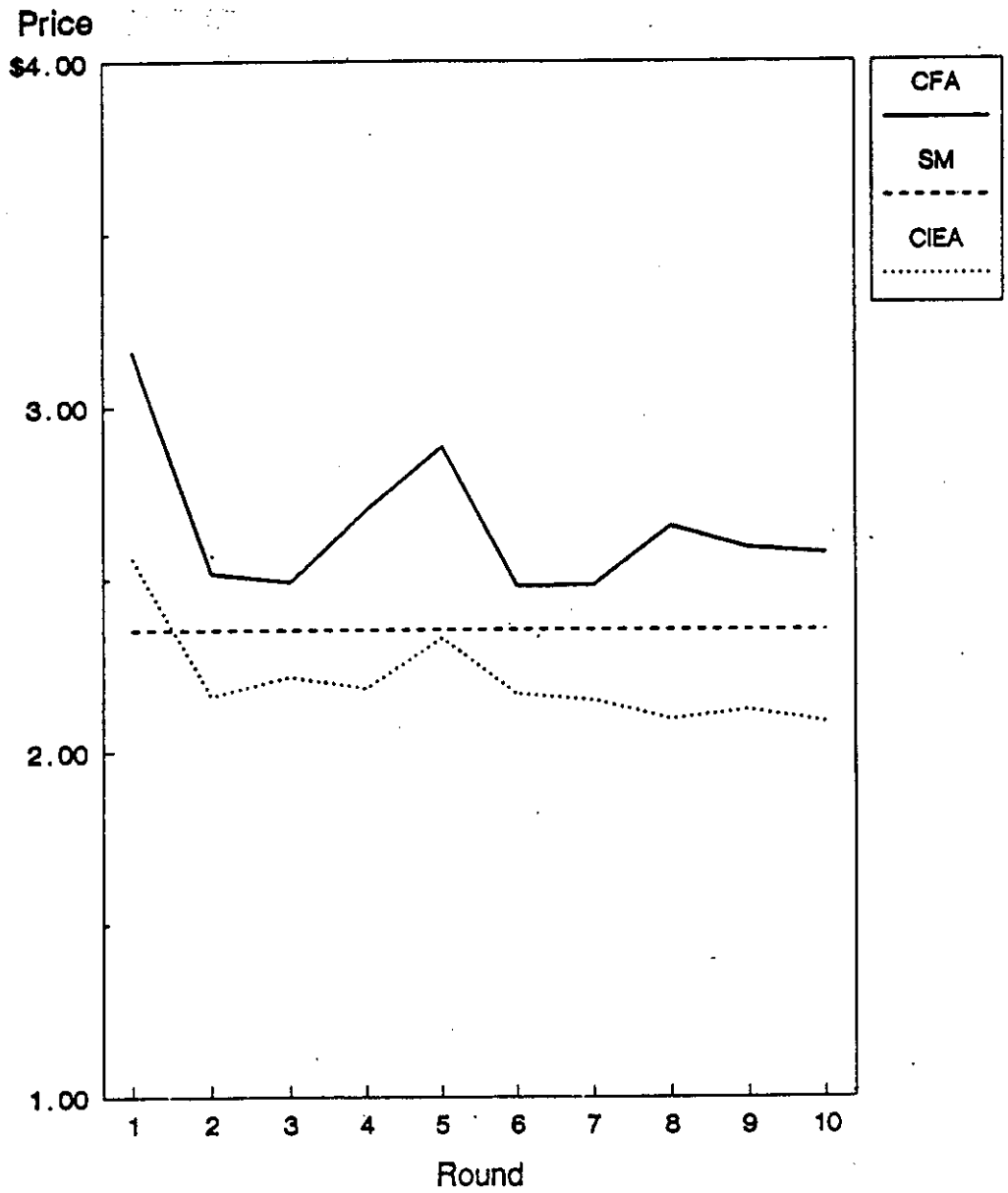


Figure 7: SM (Split the Difference Price)–CFA–CIEA – Mean Price Per Round

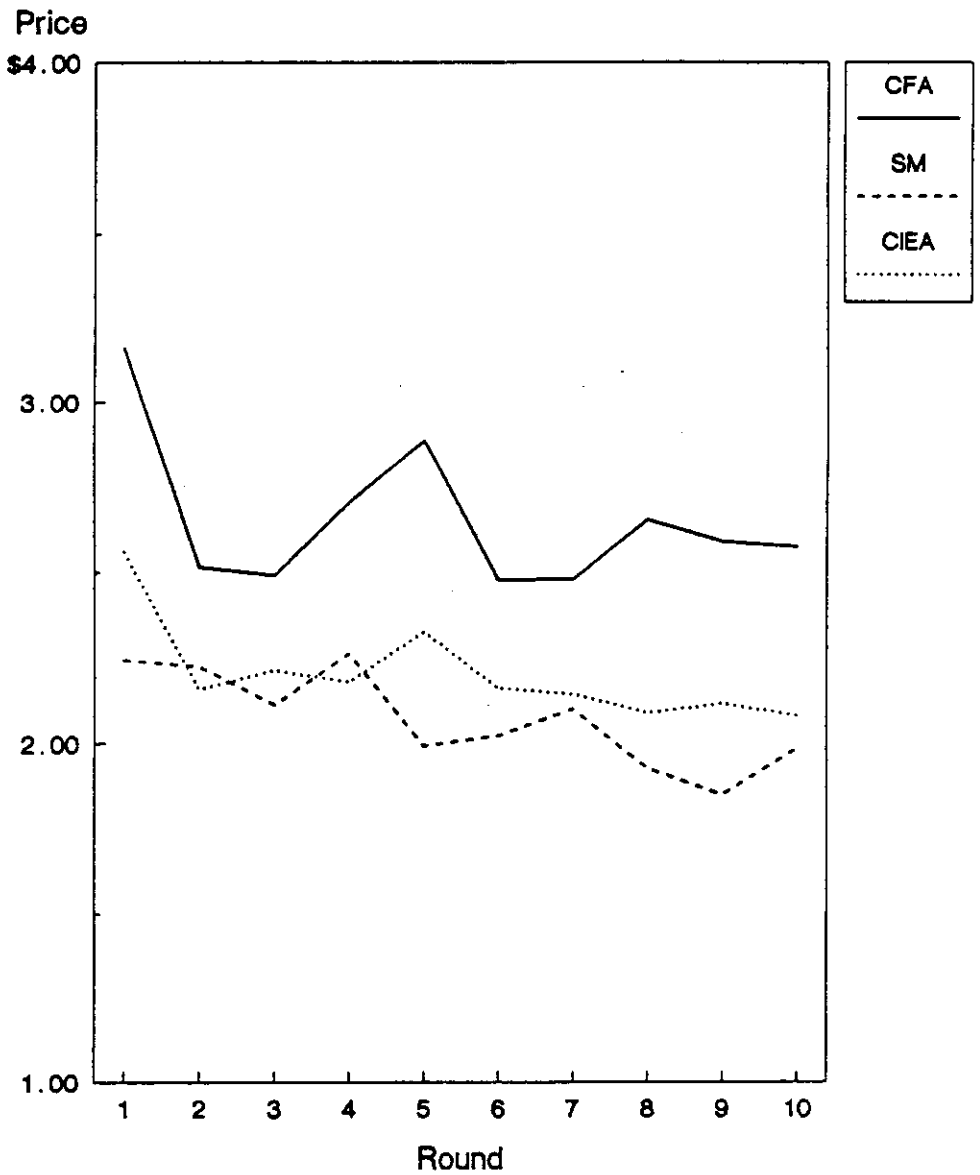


Figure 6 shows the round-by-round mean price formed under our three mechanisms where the price used to make comparisons for the SM mechanism is the mean of the 17 matches actually made in this experiments. In figure 7, we make the same comparisons this time using the round-by-round mean price that would be formed under the split-the-difference assumption. The overall trend in prices over ten rounds of the CFA experiment appears to be stable. If we omit the first round where an irrational price of $7 was formed by one pair and consider instead the movement of prices between rounds 2 and 10, we see that prices actually rose a modest 2%. On the other hand, the average price in round 10 was below the average of the first five rounds by 6%. The conclusion, then, is that CFA evidenced basic price stability over ten rounds with, at most, a modest downward trend. The actual mean price formed in each round of the CFA experiment is presented in Table 3.5 below.

Table 4.5: Mean Price Round by Round In The CFA Experiment

Round	Avg. Price
1	$3.16
2	$2.51
3	$2.49
4	$2.70
5	$2.88
6	$2.48
7	$2.48
8	$2.65
9	$2.59
10	$2.57

Unlike the CFA experiments, there is a pronounced downward trend in prices over ten rounds in the SM experiment. The average price fell by 11.5% from Round 1 to Round 10. In Round 10, it was 8% below the average price of the first five rounds. This movement downward is consistent with the trend exhibited by U-types in this experiment to increasingly lower their bids as the experiment progressed. The mean of the "split the difference " price, round-by-round, is presented in Table 4.6.

Table 4.6: Mean Split–The–Difference Price Round By Round in the SM Experiment

Round	Avg. Split The Difference Price
1	$2.24
2	$2.22
3	$2.11
4	$2.26
5	$1.99
6	$2.02
7	$2.10
8	$1.92
9	$1.85
10	$1.99

Finally, it appears that the prices formed in the CIEA experiment were stable over the experiment's horizon. While from round 1 to 10 the average price fell by 19%, from round 2 to 10 the fall was only 3%. Table 3.7 presents the round by round mean price formed in the CIEA experiment.

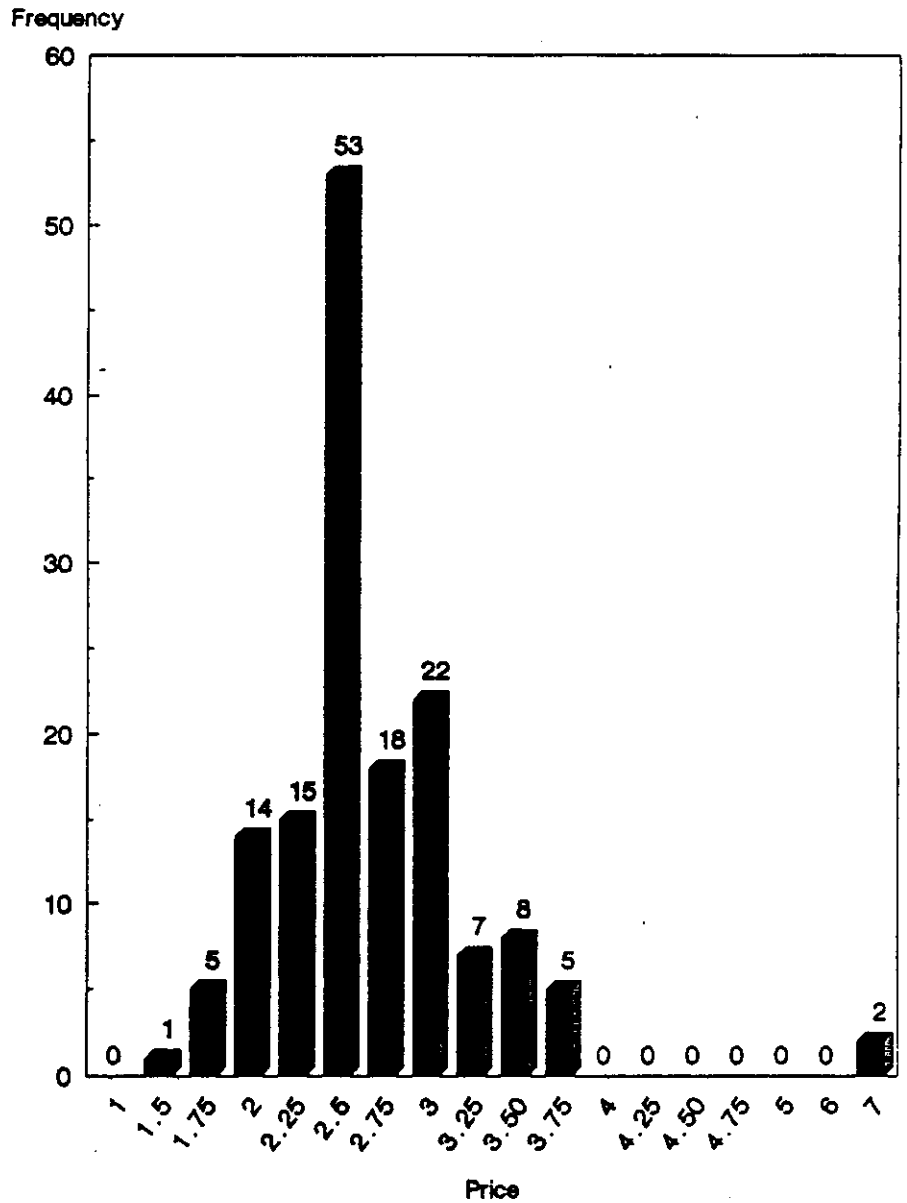
Table 4.7: Mean Price Round by Round in the CIEA Experiment

Round	Average Price
1	$2.56
2	$2.16
3	$2.22
4	$2.18
5	$2.33
6	$2.16
7	$2.15
8	$2.09
9	$2.12
10	$2.09

Figures 6a – 6c show the distribution of prices formed in the three experiments. One thing worth noting is that the CFA mechanism seems to provide prices with much smaller variances than either of the other two mechanisms. In addition, it appears less prone to generate "low" prices or prices below $1.50. More precisely, in the CFA experiment only one price was formed at the level of $1.50 or below. In the SM experiment there were 29

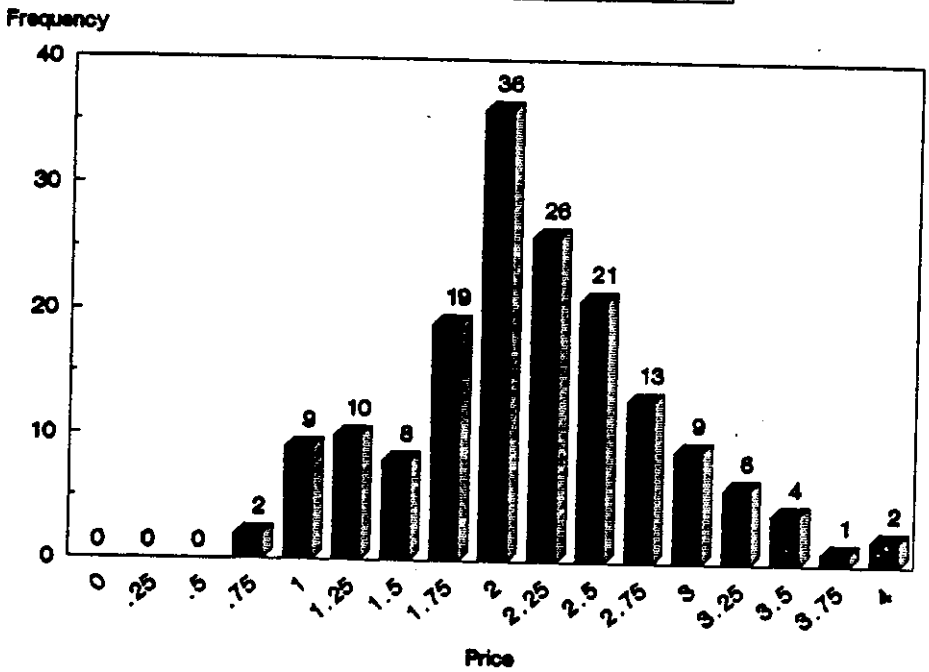
Figure 6a: CFA Experiments

Frequency of Actual Prices for All Matches



R/A

Figure 6b: SM Experiments
Frequency of Prices (With Half Fee)
All Matches



For Actual Negotiated Prices

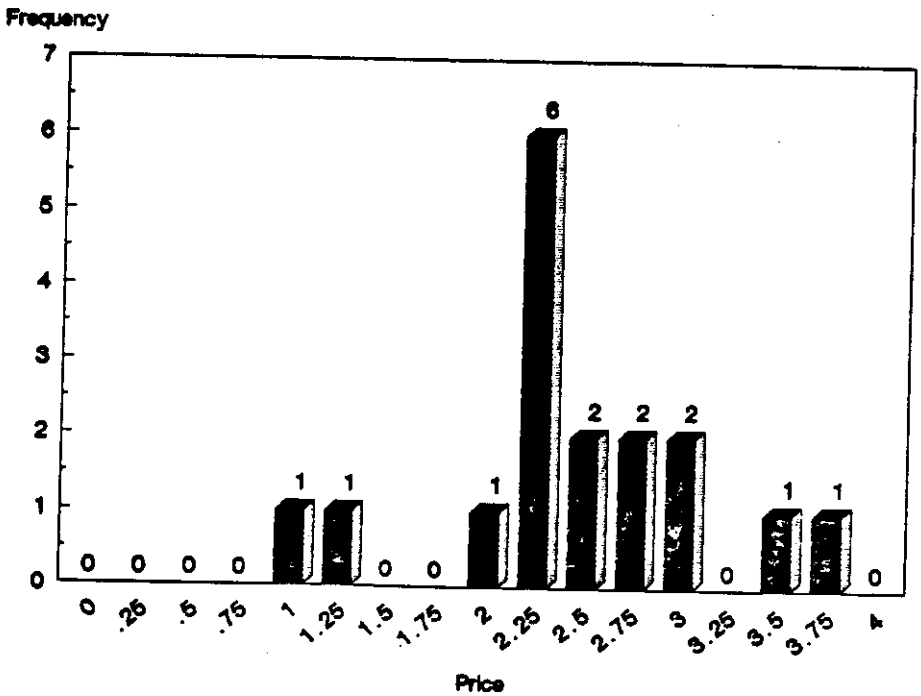
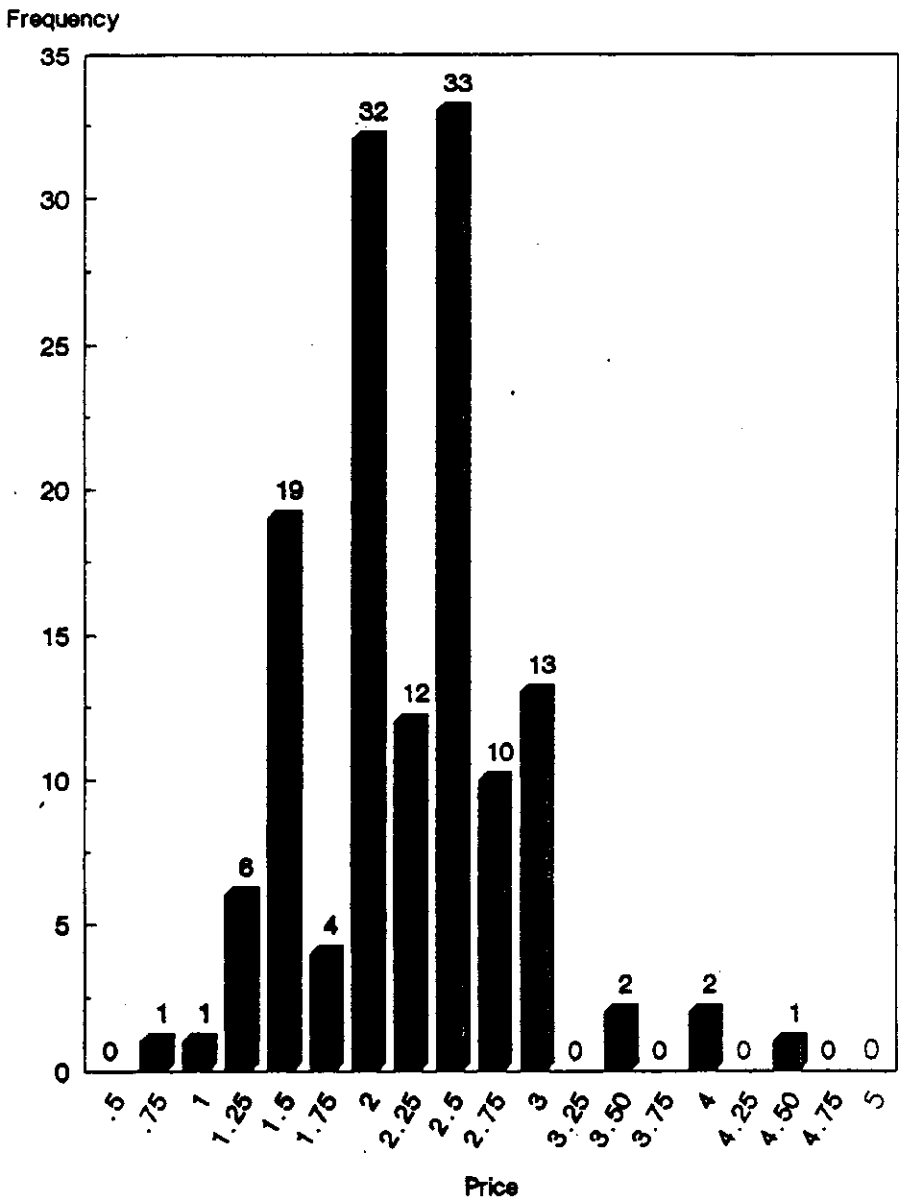


Figure 6c: CIEA Experiments
Frequency of Actual Prices for All Matches

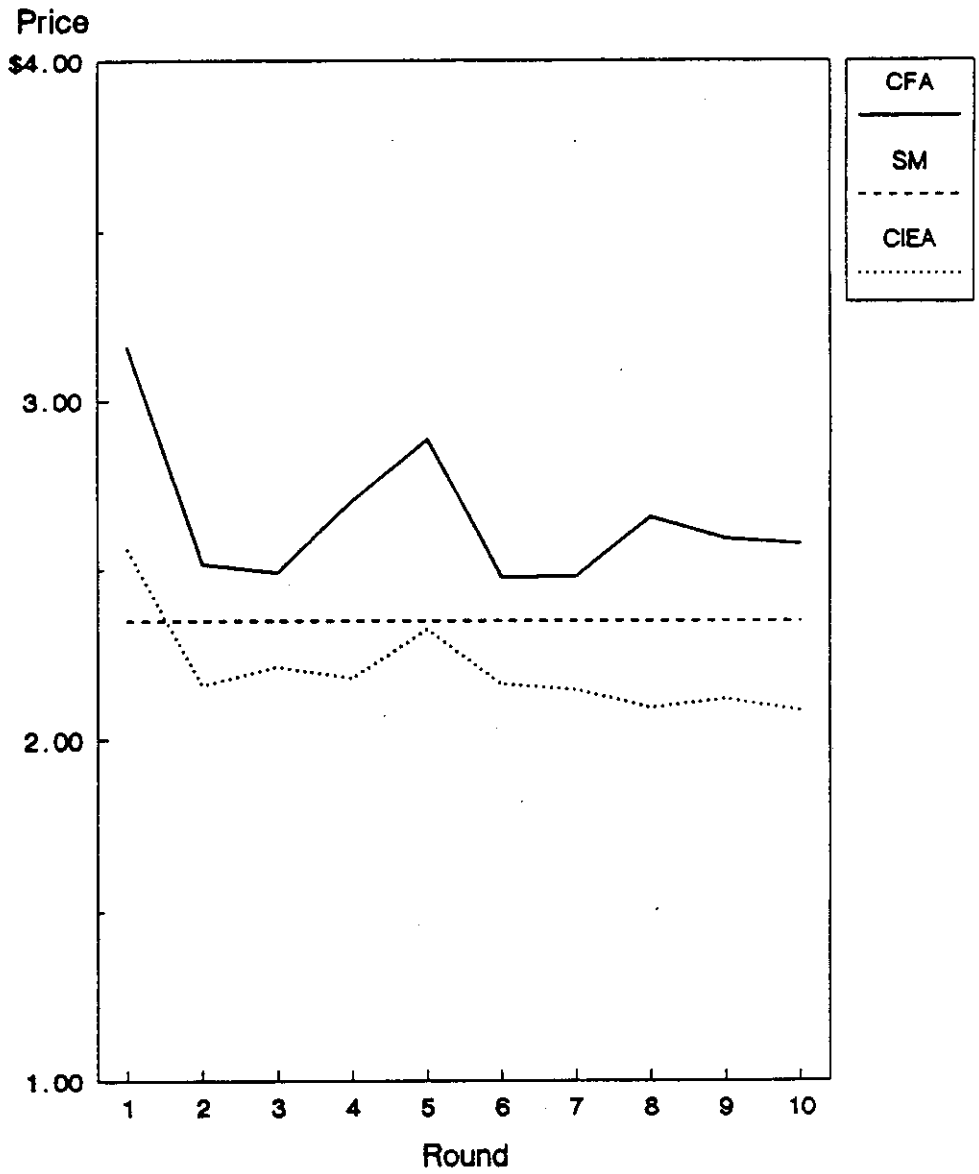


(using the "split the difference price) while in the CIEA experiment there were 27. From observing these experiments, however, it appears to us that the low prices in the SM experiment were more a function of individual learning on the part of U-types about the impact of their bids on the second stage bargaining range while in the CIEA experiment it appeared that implicit collusion took place aided by the information available to the subjects. We say this because there were two groups in the CIEA experiment who seemed to be quite successful in keeping prices low and who did so in a fairly conscious manner.

4.3: Payoffs

Since prices were highest in the CFA experiment, second highest in the SM experiments and lowest in the CIEA experiments we might expect to find that the payoffs of U-type subjects have the opposite ranking. This is in fact true. In the CFA experiment the mean payoff of U-type subjects was $1.87 per round while it was $2.00 in the SM experiment and $2.07 in the CIEA experiment. For S-types the ranking was just the opposite with the CFA experiment generating a mean payoff of $1.94 and the CIEA and SM experiments yielding payoffs of $1.72 and $1.45 respectively. While these differences appear substantial in many cases, their statistical significance was not always strong as we will soon see. These mean payoffs include within them the fact that in the CIEA and SM experiments subjects were several times left without a match. In those cases, of course, their payoffs were zero. Hence, if we condition payoffs upon whether a match was made, we see that payoffs were considerably higher for U-type subjects who were successfully matched in the SM and CIEA experiments than they were in the CFA experiment. For example, the mean payoffs per round for U-types was $1.87, $2.12, $2.29, in the CFA, SM and CIEA experiments respectively when we exclude the instances of no-matches. These differences did not appear as strongly when we look at S-types however, where the means were $1.94,$1.82, and $1.61, for the CFA, SM, and CIEA experiments respectively. In conclusion, it appears that while considerable differences appeared in the payoffs to U-type

Figure 6: SM (Actual/Constant Mean)-CFA-CIEA
Mean Price Per Round



subjects across our three experiments, those differences were even more significant in the SM and CIEA experiments for those subjects who successfully found matches.

Table 4.8 presents the results of our Mann-Whitney U tests run to investigate whether there were significant differences, round by round, between the payoffs in our three experiments. We present these tests before and after conditioning for no-matches.

Table 4.8a
Payoffs: Mann-Whitney U Tests for Differences In U-Type Payoffs Between Experiments
(No Matches Included)

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.25	.821	.639
	(.105)**	(.205)	(.261)
2	.625	.273	.273
	(.265)	(.391)	(.392)
3	.417	1.55	1.55
	(.338)	(.060) **	(.060) **
4	.835	1.00	.456
	(.201)	(.157)	(.324)
5	.835	2.28	1.73
	(.201)	(.011) *	(.041) *
6	.417	.273	.456
	(.338)	(.392)	(.324)
7	.417	1.18	.456
	(.338)	(.117)	(.324)
8	.417	.273	.091
	(.338)	(.392)	(.463)
9	.626	1.36	1.18
	(.264)	(.085) **	(.117)
10	1.04	.821	.091
	(.148)	(.205)	(.463)
Pooled data	1.95	3.43	1.22
	(.025)*	(.000)*	(.109) **

Note: The entry in each cell can be read as follows:

{ z-score
(one-tailed
probability)

* means significant at the 5% level or less
** means significant at the 10% level or less

Table 4.8b
Payoffs: Mann-Whitney U Tests for Differences In S-Type Payoffs Between Experiments
(No Matches Included)

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.04	1.73	.456
	(.148)	(.041) *	(.324)
2	.417	1.18	.825
	(.338)	(.117)	(.205)
3	.208	2.09	.456
	(.417)	(.017) *	(.324)
4	1.04	1.36	.091
	(.148)	(.085) **	(.463)
5	.208	1.18	1.55
	(.417)	(.117)	(.060) **
6	1.04	1.73	.091
	(.148)	(.041) *	(.463)
7	.835	1.91	.639
	(.201)	(.027) *	(.261)
8	1.88	1.36	.639
	(.030)*	(.085) **	(.261)
9	1.46	2.28	1.91
	(.071)**	(.011) *	(.027) *
10	1.04	2.28	1.00
	(.148) *	(.011) *	(.157)
Pooled data	1.95	3.43	1.22
	(.025) *	(.000) *	(.109) **

Note: The entry in each cell can be read as follows:
{ z-score
(one-tailed
probability)
* means significant at the 5% level or less
** means significant at the 10% level or less

In terms of statistical significance, it appears that when we include the zero payoffs that occur with no-matches, there is not a significant round by round difference in the payoffs of U-type subjects across the three experiments. For instance, significant differences appear in only one round between the CFA and CIEA experiments and only three and four times in the comparisons between CFA and SM and CIEA and SM respectively. For S-types, there does appear to be a significant difference between the CFA and SM experiments since in eight of the ten rounds the differences in means are significant.

As Tables 4.8c and 4.8d indicate, the situation changes when we investigate the payoffs of subjects only in those situations when matches are made. As we see, in these

circumstances there is a significant difference in the payoff of U-types between the CFA experiment on the one hand, and the CIEA and SM experiments on the other with significant differences appearing in seven rounds in the comparison between CFA and CIEA and in eight rounds in the comparison between CFA and SM. With respect to S-type players , we again see the CFA experiment behaving differently from the SM experiment with five rounds showing significant differences, but no real difference in the other two comparisons we make.

Table 4.8c
Payoffs: Mann-Whitney U Tests for Differences In U-Type Payoffs Between Experiments
(No Matches Excluded)

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.25	2.28	.456
	(.105)**	(.012)*	(.324)
2	.625	.456	.273
	(.265)	(.324)	(.392)
3	.208	1.55	.273
	(.417)	(.060) **	(.392)
4	1.25	1.00	.091
	(.105) **	(.157)	(.463)
5	1.04	2.46	1.1873
	(.148)	(.006) *	(.117)
6	1.46	1.73	.456
	(.071) **	(.041) *	(.273)
7	1.25	1.73	.639
	(.105) **	(.041) *	(.261)
8	.417	1.55	.456
	(.338)	(.060) **	(.324)
9	1.25	1.91	1.36
	(.105) **	(.027) **	(.085) **
10	1.46	1.73	.273
	(.071) **	(.041) *	(.392)
Pooled data	4.03	5.71	1.26
	(.000) *	(.000) *	(.103) **

Note: The entry in each cell can be read as follows:
{ z-score
(one-tailed
probability)
* means significant at the 5% level or less
** means significant at the 10% level or less

Table 4.8d
Payoffs: Mann-Whitney U Tests for Differences In S-Type Payoffs Between Experiments
(No Matches Excluded)

Round	CFA v.s.CIEA	CFA v.s.SM	CIEA v.s.SM
1	1.04	.639	.091
	(.148)**	(.261)*	(.463)
2	.417	.821	.273
	(.338)	(.205)	(.392)
3	.208	2.09	.639
	(.417)	(.017) **	(.261)
4	.626	1.36	.456
	(.265) **	(.085)	(.324)
5	.417	1.00	1.55
	(.338)	(.157) *	(.060)
6	.853	1.36	.456
	(.201) **	(.085) *	(.324)
7	.417	1.91	1.36
	(.338) **	(.027) *	(.085)
8	1.88	.821	1.73
	(.030)	(.205) **	(.041)
9	1.25	2.09	2.09
	(.105) **	(.017) **	(.017) **
10	.417	1.55	.639
	(.338) **	(.060) *	(.261)
Pooled data	2.34	4.55	2.07
	(.009)*	(.000) *	(.019)**

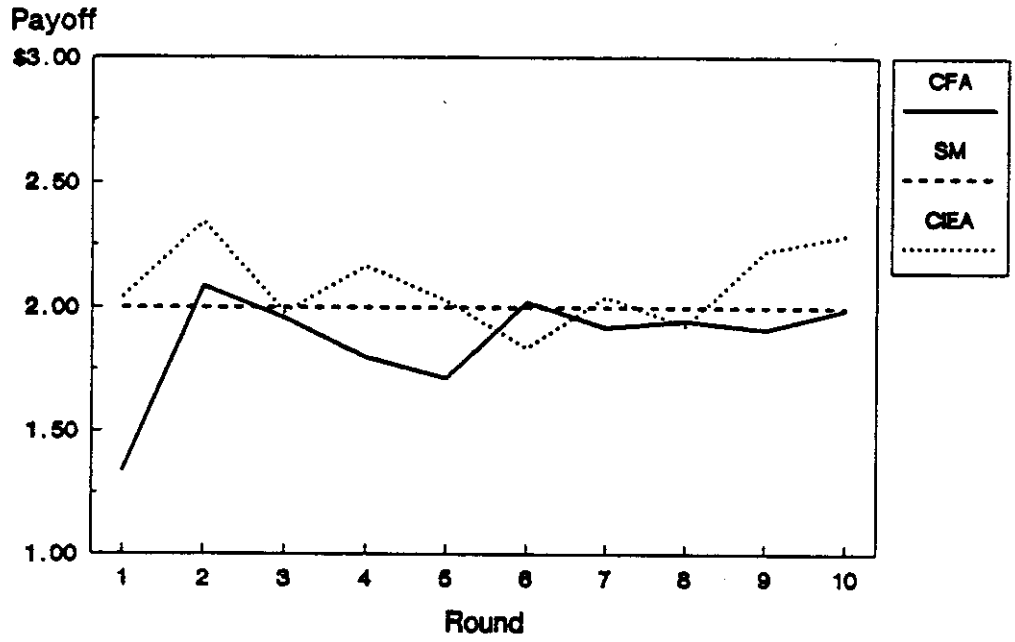
Note: The entry in each cell can be read as follows:
{ z-score
(one-tailed
probability)
* means significant at the 5% level or less
** means significant at the 10% level or less

In Figures 8 and 9 we see the mean round by round payoffs of subjects first including the no match payoffs (Figure 8) and then excluding them (Figure 9). Figure 8 confirms visually confirms the results of our statistical tests. As we see, although the CFA payoffs for U-types are consistently below those of the SM and CIEA experiments, the difference are not great. For S-types, however, the difference does appear to be considerable and in fact was statistically significant in eight of the ten rounds. In Figure 9 we see that when we exclude no matches, there are much more profound differences in the

Figure 8: CFA-SM-CIEA Experiments

Average Payoffs Per Round

U-Types including no matches



S-Types including no matches

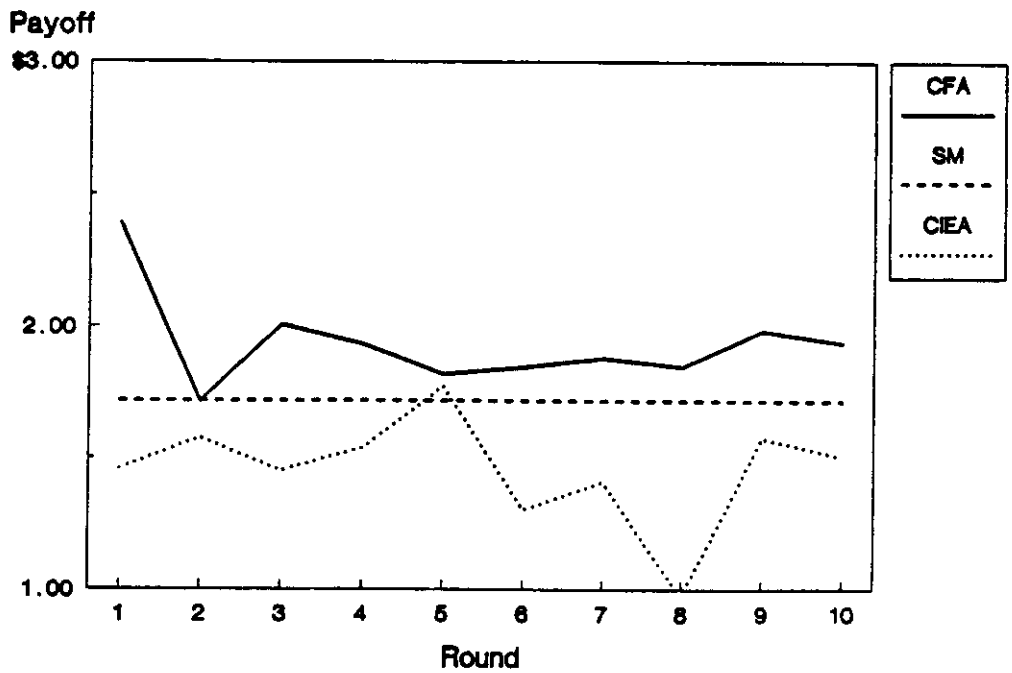
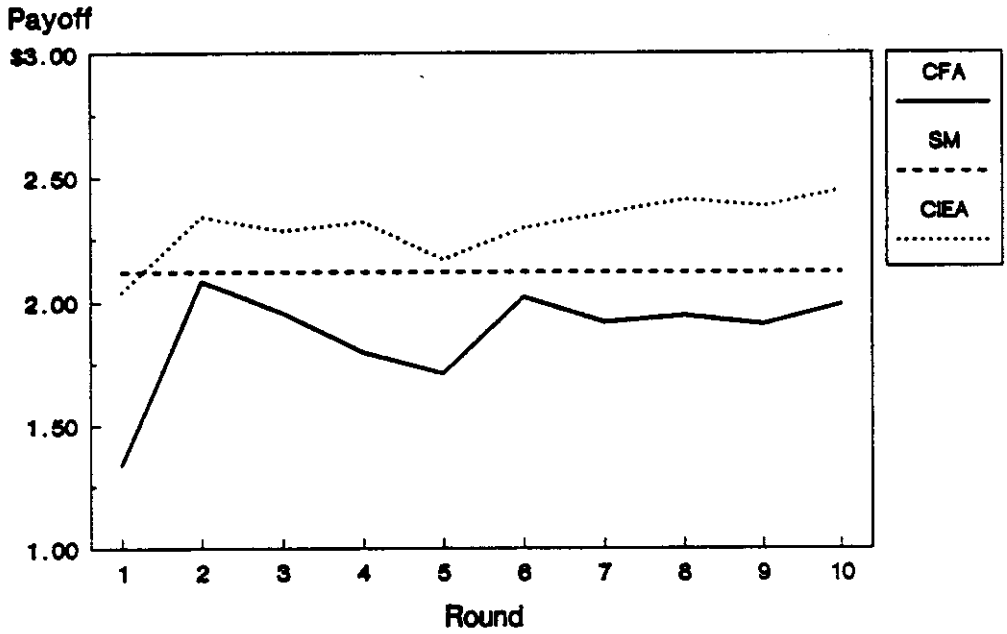


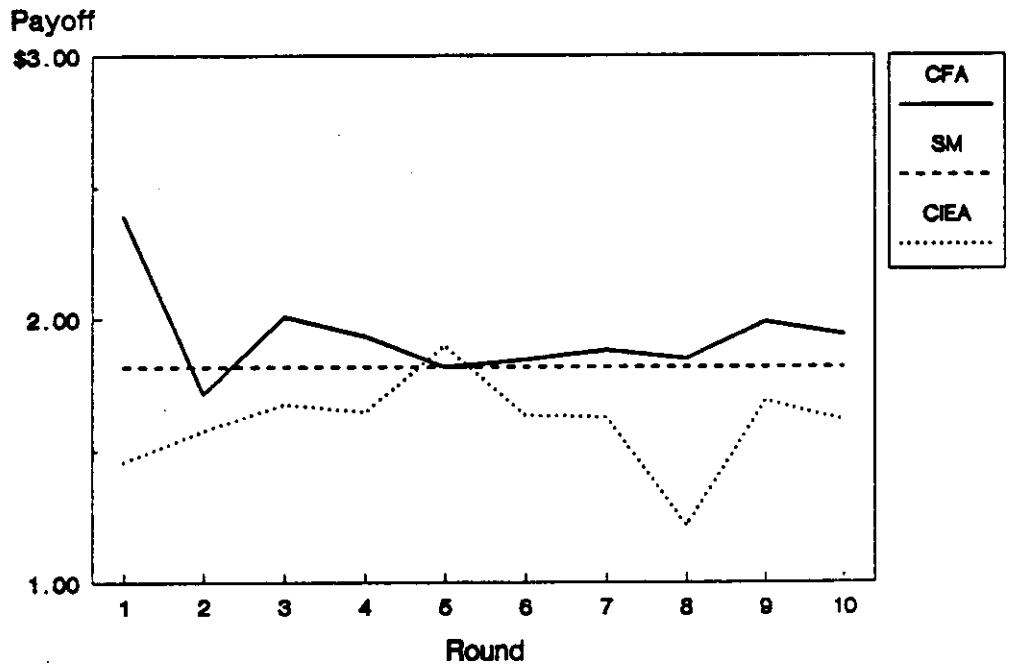
Figure 9: CFA–SM–CIEA Experiments

Average Payoffs Per Round

U–Types excluding no matches



S–Types excluding no matches



payoffs of U-type subjects with the CFA experiment uniformly demonstrating the lowest payoffs.

Section 5: Summary and Discussion

5.1: Summary

Our experiments have uncovered the following results.

1) Although visually it appears that the CFA mechanism achieved the greatest efficiencies, these differences are not borne out statistically. However, a mechanism's efficiency is influenced by two factors; its ability to match people and its ability, to match people optimally. On these grounds the three mechanisms differed. While the CFA mechanism was extremely successful in avoiding no-match situations, (it determined none of them) it was less successful in matching people in an optimal (surplus maximizing) manner failing to do so in 31 of 150 opportunities. The opposite was true of the SM mechanism. While it determined a considerable number of no-matches, (14 out of 180) it was relatively successful in avoiding sub-optimal matches (only 20 out of 180). The CIEA mechanism suffered from both problems determining an equal number of no- and sub-optimal matches; still it surpassed CFA in its ability to avoid sub-optimal matches.

These results are consistent with others found by Hoffman and Spitzer (1982) and Radner and Schotter (1989 forthcoming). In both of those experiments it was found that face-to-face negotiation is extremely successful in avoiding no-trade or in this case, no-match behavior.[7] Since the CFA mechanism is a voice-to-voice mechanism which is similar to face-to-face bargaining it appears that such behavior carries over to it. In Radner and Schotter (1989) it was also observed that with almost 100% accuracy the face-to-face mechanism they used led to trades in all situations in which it was profitable

[7] In both of those experiments if a trade is consummated it automatically is an optimal trade so they always yielded what we would call 100% surplus efficiencies.

to do so. Similar results were found by Hoffman and Spitzer yet Roth (1979) reports that when bargainers communicate through a computer terminal by written messages to anonymous partners, a considerable number of no-trades do occur. Hence the CFA mechanism seems to share the property that many face-to-face mechanisms share which is that it is non-wasteful in its ability to avoid senseless no-trades or no-matches.

It is also interesting to note that in the only other experimental investigation of a telephone market we know of, the Hong and Plott (1982) experimental study of the pricing of barge traffic along the Mississippi, they found that the mechanism yielded surplus efficiencies ranging between 83% and 94% with an overall average of 91%. These efficiencies are comparable to those found for the CFA experiment which was itself a telephone market.

2) In the CIEA and CFA mechanisms, there appears to be a difference as to <u>when</u> during the five minute round we find trades taking place. Al Roth has commented elsewhere (1988) that when negotiations are made through indirect messages rather than by voice contact, and there is a time limit set for bargaining, trades seem to consummate at the very end of the trading period, almost at the last second. On the other hand, Radner and Schotter (1989) have remarked that in their face-to-face bargaining experiment transactions were consummated very early on in the bargaining period and there was certainly no tendency to exhibit any deadline effect. Similar results were found in the CIEA and CFA experiments which were respectively message and face-to-face mechanisms. In the CIEA experiment almost every round lasted the full five minutes allotted to it with many trades taking place during the 10 second count-down time. In the CFA experiment, however, this was not the case since many if not most trades were made quickly and few trading periods lasted the full five minutes.

3)Prices tended to be higher in the CFA experiments followed by the SM and then the CIEA. The difference between the CFA mechanism and the others is statistically significant. The fact that the CFA mechanism yielded higher prices than the CIEA mechanism is, at first, somewhat surprising since from the results obtained on double oral auctions one is led to believe that when the strategy space of one side of a market is restricted so that they can only accept or reject bids but not make counter offers, their payoffs should rise (see Smith (1982) for a discussion of this point). In our experiments just the opposite occurred. We find that prices in the CIEA mechanism -- a mechanism where the S-types are relatively passive-- were lower than those in the CFA mechanism where they were active. We attribute this to two factors. First the double oral auction results may not be expected to carry over here since neither of these mechanisms is specifically of that type. Those result may be very institutionally sensitive. Second, we feel from observing the CIEA mechanism that it may be very vulnerable to collusion on the part of the U-type subjects. Such collusion is made possible by the common knowledge of bids made and by the opportunities available to U-types to punish others when they detect an attempt to raise price.

4) The fact that the mechanisms can be ranked in a statistically significant manner with respect to prices does not mean that they adhere to the same rankings when we look at payoffs. The reason for this is that the expected payoff from a mechanism must include in it the probability of being matched. Even though the SM and CIEA mechanisms yielded prices that were beneficial to the U-types, they produced a sufficient number of no-matches and sub-optimal matches (i.e. less profitable matches so as to diminish the profitability of the mechanism for the U-type subjects. However, if we condition the subjects' payoffs on whether or not they were matched, then we find that for U-type

subjects who were successfully matched both the SM and CIEA mechanisms were significantly better than the CFA mechanism. The opposite was true for S-types.

5) In the SM mechanism the U-type subjects misrepresent their preferences far more than do the S-types. This is true despite the fact that the mechanism treats them symmetrically in the sense that misrepresentations by the S type subjects determine the lower bound of the negotiation range while those by the U-types determine the upper bound. Hence we had no a priori grounds on which to expect such a difference. The fact that one appeared is consistent with the Radner -Schotter (1989) experiments which found that in a symmetric sealed bid simultaneous move mechanism, buyers tended to shave their bids more than sellers. Those asymmetries could not be sufficiently explained by Radner and Schotter; likewise, we have no satisfactory explanation for our finding here.

5.2: Discussion

There are many criteria which should be met by an allocating mechanism before we recommend it for implementation in the real world. These criteria combine the theoretical properties that economists cherish with the practical concerns of practitioners. In this section we offer a number of such criteria and discuss how successful our three mechanisms were in satisfying them. While no mechanism can possibly satisfy them all, we do expect that a satisfactory mechanism will go at least part of the way in satisfying some of them:

1) Understandability

Our first criterion requires that whatever mechanism we use, it be understandable to those agents who are going to use it. By understandable we can mean one of two things. One is that the participants simply understand the rules of the mechanism and hence physically know what to do in it. A more demanding criterion would require that the participants understand the theory underlying the mechanism. While our three mechanisms were easily understood by our subjects in the sense that they quickly became comfortable

playing the games that these mechanisms determined, the subjects probably had a lesser understanding of the theory underlying the SM mechanism. In fact only a rudimentary explanation of this theory was even offered to them. Hence they tended to treat it like a black box into which they place their bid and get a match and bargaining range as an output. Still, the U-type subjects clearly began to understand, at least statistically, the relationship between their bids and the prices that they might have to eventually pay.

2) Fairness-- Strategic Symmetry

If a mechanism is ever going to be employed it must be perceived as being "fair". In this context we mean that the mechanism is "strategically fair" in that the strategy sets of the agents are symmetric: any strategy available to one side of the market has a comparable strategy available to the other side. In addition, each side has strategies that affect the payoff function in an equivalent manner given the action of others. The CFA mechanism clearly meets this criterion and upon inspection so does the SM mechanism. The CIEA mechanism, however, does not give the S-type subjects the same strategic capabilities as it does the U-type subjects since they cannot make counter offers to the bids made by the other side. This fact was never commented upon by our subjects, a response quite unlike the anger displayed by S-type subjects during a modified version of the SM mechanism that we ran where no bargaining was allowed and where the price of the match was simply the match price p_j.

3) Efficiency

As we know, efficiency is the ultimate economic criterion. Still a successful mechanism may have to trade off efficiency for other characteristics that may be desirable. As mentioned above, all three of our mechanisms were comparable in terms of efficiencies but achieved these efficiencies in different ways. While the SM mechanism was relatively successful in making optimal matches when matches were made, it was relatively less successful in making matches than was the CFA mechanism. CIEA seemed to suffer from

both afflictions and, while not shown statistically, seemed to perform the worst of the three.

4) Strategic Robustness

A successful mechanism should be robust against small or even considerable mistakes or miscalculations on the part of the agents using it. For example, in the SM mechanism we see that it takes a considerable amount of misrepresentation on both the parts of the S and U types in order to produce a no-match outcome. This fact is encouraging since it means that, except for large deviations which we might expect to disappear as time goes on, the SM mechanism might be expected to yield high efficiencies. It is not clear how mistakes or miscalculations can be measured or observed in the CFA or CIEA since the strategies there are so unstructured. Still mistakes are made in the CFA mechanism when deals are consummated prematurely while in the CIEA mechanism subjects can miscalculate when they play a game of timing during the last ten seconds of a round and move too late.

5)Personality Robustness

In addition to being robust with respect to strategic actions we might like our mechanism to be robust to the personalities who use it. For example, if the outcomes of a mechanism are greatly influenced by the actual people who use it we can expect a larger than usual variance in outcomes and a greater sense of uncertainty about the mechanism. Anonymous mechanisms in which people play once and only once are probably the most personality robust. From our observation of the experiments we feel that the CIEA and CFA mechanisms exhibit the most severe group effects. What this means is that the CIEA and CFA mechanisms are most susceptible to having the outcome of its deliberations affected by the actual people used in the experiment. We feel that this is true in the CFA experiments because negotiations are voice-to-voice and hence susceptible to personalities, while with the CIEA mechanism U-type subjects had more room to coordinate a collusive

buying pattern. Under CIEA, when a group of U-types saw their common interest clearly, they were very successful in securing extremely favorable prices for themselves. When they did not, prices were as high or higher than observed elsewhere.

6) Agent Profitability

New institutions are never imposed in an historical vacuum. In almost every instance where a new institution is called for it replaces an old one. When it does so it must make sure to provide a profitable role for all actors who participated in the previous institution especially if those agents have the ability to veto the use of the new mechanisms. In addition, a new mechanism would have a better chance of being implemented if it were "in the idiom" of the one it is replacing. For example, if an industry has historically set its wages by bargaining, a new wage setting institution might have a better chance of being used if it provided a role for bargaining in it as well. To illustrate this point, in the baseball industry we have a set of agents who have historically played an active role in the wage setting process. These includes the team owners, the players association, the players themselves and the agents of the players. In addition, salaries have been set by negotiation. Hence any new mechanism might do well to provide a role for all of these actors as well as preserving the negotiation process currently employed. All three of our mechanisms do this, albeit in different ways. Probably the biggest departure from the past is the SM mechanism because before the bargaining process takes place there is a prior non-cooperative game that must be played whose outcome determines the parameters of the bargaining. To the extent that this prior game helps structure and focus the bargaining it may be a valuable addition to the regular bargaining process.

7) Collusion Freeness

If a mechanism is to be acceptable to economic agents, it should be resistant to collusive behavior among the participants using it. Collusion is most easy when participants on one side of the mechanism can cheaply signal their intentions and when defections from

an implicitly agreed to convention of behavior are easily detected. In our opinion, of the mechanisms observed, CIEA was the one most susceptible to collusion. This was true because U–types could easily signal their intentions through the bids they submit which were common knowledge for all other U–types (and S–types). In a number of instances, a clear "meeting of minds" existed among the U–types, the effect of which was to keep prices low. Evidence of collusion was hard to find in our other experiments.

While our results must be considered tentative at this point, we do feel they have shed considerable light on the behavioral and operational mechanics of the bidding systems studied. Our experiments have verified our suspicions about the way the current system works. They further suggest that some features of the formal matching mechanism (SM) might prove beneficial to Baseball's free agency. Some additional experiments are clearly in order, however, before definitive conclusions can be reached.

References

Damange, G. and Gale, D., "The Strategy Structure of Two-Sided Matching Markets, Econometrica, vol. 53, 1985, pp. 873-888.

Gale, D. and Shapley, L., "College Admissions and the Stability of Marriage," American Mathematical Monthy, vol 69, 1962, pp. 9-15.

Hoffman, E., and Spitzer, M. " The Coase Theorem: Some Experimental Tests", Journal of Law and Economics, vol. 25, 1982, pp. 73-98.

Hong, J. and Plott, C. "Rate Filing Policies for Inland Water Transportation: An Experimental Approach", The Bell Journal of Economics, vol. 13, Spring 1982, pp. 1-20.

Leonard, H., "Elicitation of Honest Preferences for the Assgignment of Individuals to Positions," Journal of Political Economy, vol. 93, no. 3, 1983, pp. 461-480.

Radner, R. and Schotter, A. " The Sealed-Bid Mechanism: An Experimental Study", Journal of Economic Theory, forthcoming 1989.

Roth, A. and Malouf, M. " Game Theoretic Models and the Role of Information in Bargaining", Psychological Review, vol. 86, 1979, 574-594.

Roth, A., "The Economics of Matching: Stability and Incentives," The Mathematics of Operations Research, vol.7, 1982, pp. 617-628.

Roth, A., "The Evolution of the Labor Market for Medical Interns and Residents: A Case Study in Game Theory," Journal of Political Economy, 1984a, pp. 991-1016.

Roth, A., "A Misrepresentation and Stability in the Marriage Problem, "The Journal of Economic Theory, vol. 34, 1984b, pp. 383-387.

Roth, A., "The College Admissions Problem is not Equivalent to the Marriage Problem," Journal of Economic Theory, vol. 36, 1985a, pp. 277-288.

Roth, A., Murnighan, K. and Schoumaker, F., "The Deadline Effect in Bargaining: Some Experimental Evidence." vol. 78, American economic Review, 1988.

Shapley, L and Shubik, M., "The Assignment Game I: The Core," International Journal of Game Theory, vol. 1, 1972, pp. 111-130.

Smith, V., "Reflections on Some Experimental Market Mechanisms for Classical Environments," in, Choice Models in Marketing, Supplement 1, pp. 13-47, JAI Press 1982.

APPENDIX

INSTRUCTIONS

SM INSTRUCTIONS

General

This is an experiment in the economics of computerized resource allocation. The instructions are simple and if you follow them carefully you could earn a considerable amount of money which will be paid to you at the end of the experiment. Funding for this experiment has been provided by various research foundations.

You will participate in a computerized market lasting 10 periods. The market consists of two types of participants which we will call U−types and S−types. Your type (U or S) will remain the same over all 10 periods. (Look at the upper right hand corner of your instruction sheet to see which type you are).

The object of the market is to match participants of opposite types. That is, each S type player is to be matched with at most one U type player and vice versa. In each period, there are 3 S players (S_1, S_2, S_3) and 3 U players (U_1, U_2, U_3). Each S−type will be matched with at most one U−type and each U−type will be matched with at most one S−type. How much money you earn depends on which player of the opposite type you are matched with, on the price determined for that match, and on the fee for that match which will be negotiated by you with the subject you are matched with. This is explained below.

How Your Earnings are Calculated

In each period you will be given a schedule detailing the information available to you in that round of the experiment. For U type participants, this schedule gives you the value of being matched with a specific S type. For S–type participants, this schedule lists the cost associated with being matched with a specific U type. Note that you will receive a new schedule at the beginning of each period. This schedule is your own private information, do not reveal it to anyone. For example, a player of type U might have the following schedule:

For Type U Players

Type U Valuations

Player	Value (in dollars)
S2	50
S1	20
S3	10

We read the schedule as follows. This U–type player gets 50 dollars if matched with player S2, 20 dollars if matched with player S1, and 10 dollars if matched with player S3. In each period you will be matched with one of the three S players. Your earnings for that period will be the stated value from your schedule, minus a "matching price" and minus another charge or "fee" that will be deterined in bargaining between you and your match pair. We will discuss how this matching price and bargaining fee is determined

shortly. Hence, if this U type is matched with a player of type S2, his (her) payoff would be 50 dollars minus the price of the match and minus the fee that is negotiated. . If that price is 15 and the fee 12, the payoff is π=\$50 $-$\$15$-$ 12 = \$23. If a U player is not matched with an S player, then his(her) payoff for that period is 0.

For Type S Players

Type S Costs

Player	Cost (in dollars)
U2	30
U1	20
U3	10

We read the schedule as follows: This S type player must pay 30 dollars if he is matched with player U2, 20 dollars if matched with U1 and 10 dollars if matched with U3. This cost will then be subtracted from the matching price. Hence, if this player is matched with a player of type U1, his (her) payoff would be equal to the price of the match minus 20 dollars plus the bargaining fee negotiated between this player and their match mate. If the matching price is \$25, and the fee is \$12, then the payoff will be \$25 $-$ \$20 + \$12 = \$17. If a S player is not matched then his(her) payoff for that period is 0. All you will know is your own values (cost) which will change in each period of the experiment.

Value–Cost Matrices

U players will always have one value of 50, one value of 45, and one value of 40, although the S players to whom these values are attached will change from round to round. S players will always have one cost of 20, one cost of 10 and one cost of 5 for U–type players, although the U players to whom these costs are attached will change from round to round. However, you will not know the schedule for any subject, but yourself. Based on the information given to you in each period, the value and cost of each person determines a pair of matrices. An example of such a pair is given below. By combining the schedules of each S and U player, we can construct value–cost matrices.

Matrix 1

Type–S Costs

	S1	S2	S3
U1	5	5	20
U2	20	10	10
U3	10	20	5

Matrix 2

Type U Values

	U1	U2	U3
S1	40	50	50
S2	45	45	45
S3	50	40	40

These matrices are read by looking down the columns. For example, looking down the second column in matrix 1, we see that the cost to player S2 will be 5 if matched with player U1, 10 if matched with player U2, and 20 if matched with player U3. Looking down column 1 in matrix 2, we see that the value of a match to U1, is 40 if matched with S1, 45 if matched with S2, and 50 if matched to S3. These numbers are not necessarily the ones you will face in any round of the experiment. However, if these numbers did exist then they would specify the cost to players of type S of being matched with any player of type U (matrix 1) and the value to any U−type player of being matched to a player of type S (matrix 2).

Experimental Procedures:

Remember that your value (cost) schedule will change at the beginning of each period. Therefore, in each period of the experiment, you will first check your value or cost for that period. These values or costs will be posted on your screen.

If you are a player of Type U:

When you sit down at the computer your computer screen will appear as follows:

	1	2	3	4	5	6	7	8	9
Round	Bid Limits			Actual bids			Match	Fee or Bargaining Limit	Match Price
	S_1	S_2	S_3	S_1	S_2	S_3			
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

As the experiment proceeds the columns of this chart will be filled in. When each round begins your values or bid limits for players S_1 S_2, and S_3 will be filled in in columns 1–3. These numbers tell you the maximum you can bid for each player.You first must determine a "maximum bid" for each type of S player. To enter your maximum bids, the computer will first ask you at the bottom of your screen,

<<What is your maximum bid for player S1>>?

You will respond by typing a number between 0 and your value as specified on your screen for that round and hitting the enter (return) key. Note that your maximum bid for any S player cannot exceed the stated value for that S player listed on your schedule. The computer will then respond by asking you to confirm your bid. It will state

<<You bid ----- for player S1; do you wish to modify it>>?

If your answer is no, type an N, and you will enter that bid in column 4. If your answer is yes, type a Y, and the computer will again ask you to enter another bid for player S1. It will then proceed to ask you your bids for players S2 and S3 in order, using the same procedure. When you have completed entering your information, the computer will state

<<please wait for matches>>

at which time it will wait for information to be entered by the other subjects in your group. This "maximum bid" will help determine which S–Type player you will be matched with and the price of the match. It will not necessarily be the price of the match. That will always be equal to or lower than this bid and generally strictly lower. What is true is that the higher the "maximum bid" you submit for a player of type S, the greater the chance of being matched with that player. The exact price depends on the bids of the other subjects.

If you are player of type S

When you sit down at the computer your computer screen will appear as follows:

	1	2	3	4	5	6	7	8	9
Round	Bid minumums			Actual bids			Match	Fee or Bargaining Limit	Match price
	U_1	U_2	U_3	U_1	U_2	U_3			
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

As the experiment proceeds the columns of this chart will be filled in. When each round begins your costs or bid minimums for players U_1 U_2, and U_3 will be filled in in columns 1–3. These numbers tell you the minimum you must bid for each player. To enter your minimum bids, the computer will first ask you at the bottom of your screen,

<<What is your minimum bid for player U1>>?

You will respond by typing a number at least as large as your cost specified in the beginning of that round and hitting the enter (return) key. (You cannot enter a lower "minimum bid" than your value). The computer will then respond by asking you to confirm your bid. It will state

<<You bid ––––– for player U1; do you wish to modify it>>?

If your answer is no, type an N, and you will enter that bid in column 4. If your answer is yes, type a Y, and the computer will again ask you to enter a bid for player S1. It will then proceed to ask you your bids for players S2 and S3 in order, using the same procedure. When you have completed entering your information, the computer will state

<<Please wait for matches>>

at which time it will wait for information to be entered by the other subjects in your group.

S players must bid to determine which U player they will be matched with for that period. The lower the "minimum bid" submitted for a player, the better the chances of being matched with him. While the price determined for your match will never be lower than your bid, its exact value will be determined by the bids of the other subjects. The opposite is true for high "minimum bids".

Matching and the price of your match (what the computer does with your messages)

The computer will take all of the information submitted to it by all of the subjects, and determine whom will be matched with whom and the prices to be paid. It does this by finding that match which maximizes the sum of the differences between the stated "maximum bids" of the U–type subjects and "minimum bids" of the S–type subjects. The price paid for any match is determined in a two step procedure. First, the computer will determine a "match price" by finding the lowest set of prices for which the supply for any player of type S equals the demand for that player by type–U subjects. This means that the computer will find the lowest price which maximizes the sum of the differences between maximum and minimum bids and which also makes it such that there is never two U–types who at those prices, prefer the same S–type player. In short, the computer will find the lowest set of "competitive" or "market" prices taking all of the information submitted to it into account. Next, each pair of matched subjects will bargain over an additional "fee" for the player of type U to pay. The range within which this fee must be set will also be given to each pair of subjects who are matched. This fee is a fee that the

U−type player must pay to his matched partner and represents a payment for the right of participating in the market. You will be given 5 minutes to negotiate such a fee and if you fail to do so we will pick a value for this fee at random by choosing a number betyween 0 and your maximum fee with equal probability. If you come to an agreement, we will have you sign a contract sheet. Your final price for the match will be the sum of your match price and the entrance fee you negotiate.

Hence, after each round in columns 7−9 the computer will indicate the person you are matched with, the match price, and the fee to be bargained over. If you are matched with no one, it will place an * in column 7.

Final Payoffs

Your final payoff in the experiment will be determined as follows; You will enter information as described above for 10 periods and receive matches, matching prices and bargaining ranges for each round. At the end of the experiment the experimental administrator will draw a ball from a bingo cage which contains 10 balls each with a number on it from 1−10. The round picked at random in this way will be the round which will "count" in the sense that the matches and bargaining ranges in that round will be the ones that determine your payoff. Players will then be matched with their counterparts in that round and brought into rooms to bargain and determine a your fee. The payoffs determined by this price and negotiated fee will be the only one that counts. Your final payoff will be your payoff in this round minus $3.00. If you were not matched with anyone in that round, you will receive a $6.00 payoff.

CIEA INSTRUCTIONS

General

This is an experiment in the economics of resource allocation. The instructions are simple and if you follow them carefully you might earn a considerable amount of money which will be paid to you at the end of the experiment. Funding for this experiment has been provided by various research foundations.

You will participate in a market lasting 10 rounds or market periods. At the beginning of the experiment, you will be assigned to be one of two type of players: denoted by U or S respectively. Your player type (U or S) will remain the same over all 10 periods. (Look at the upper right hand of your instruction sheet to see which type you are). The object of the market is to match yourself with a player of the opposite type and determine a price for that match. That is, each S type player will attempt to form a match with one U−type subject and each U−type subject will attempt to form a match with one S−type subject.

In each period, there are 3 S players (S_1, S_2, S_3) and 3 U players (U_1, U_2, U_3). How much money you earn depends on which player of the opposite type you match yourself with and on the price determined for that match. How this price is determined is explained below.

How Your Earnings are Calculated

In each period you will be given a schedule. For U players, this schedule gives you the value of being matched with a specific S type. For S players, this schedule lists the cost associated with being matched with a specific U type. Note that you will receive a

new schedule at the beginning of each period. This schedule is your own private information, do not reveal it to anyone. For example, a player of type U might have the following schedule:

For Type U Players

Type U Valuations

Player	Value (in dollars)
S2	5
S1	2
S3	1

We read the schedule as follows. This U–type player gets 5 dollars if matched with player S2, 2 dollars if matched with player S1, and 1 dollars if matched with player S3. Your earnings for that period will be the stated value from your schedule, minus a "contract price". We will discuss how this contract price is calculated shortly. Hence, if this U–type is matched with player S3, his (her) payoff would be 5 dollars minus the price of the match. If that price is 1.5, the payoff is π = \$5 − \$1.5 = \$3.5. If a U player is not matched with an S player, then his(her) payoff for that period is 0.

For Type S Players

Type S Costs

Player	Cost (in dollars)
U2	3
U1	2
U3	1

We read the schedule as follows: This S type player must pay 3 dollars if he is matched with player U2, 2 dollars if matched with U1 and 1 dollar if matched with U3. This cost will then be subtracted from the contract price. Hence, if this player is matched with a player of type U1, his (her) payoff would be equal to the price of the match minus 2 dollars. If the contract price is \$2.5, then the payoff will be \$2.5 −\$2 =\$.5. If a S player is not matched then his(her) payoff for that period is 0. All you will know is your own values (cost) which will change in each period of the experiment.

Value–Cost Matrices

U players will always have one value of 5, one value of 4.5 and one value of 4, although the S players to whom these values are attached will change from round to round. S players will always have one cost of 2, one cost of 1 and one cost of .5 for U-type players, although the U players to whom these costs are attached will change from round to round. However, you will not know the schedule for any subject, but yourself. Based on the information given to you in each period, the value and cost of each person determines a pair of matrices. An example of such a pair is given below. By combining the schedules of each S and U player, we can construct value-cost matrices.

Matrix 1

Type-S Costs

	S1	S2	S3
U1	.5	.5	2
U2	2	1	1
U3	1	2	.5

Matrix 2

Type-U Values

	U1	U2	U3
S1	4.5	5	5
S2	4	4.5	4
S3	5	4	4.5

These matrices are read by looking down the columns. For example, looking down the second column in matrix 1, we see that the cost to player S2 will be .5 if matched with

player U1, 1 if matched with player U2, and 2 if matched with player U3. Looking down column 1 in matrix 2, we see that the value of a match to U1, is 4.5 if matched with S1, 4 if matched with S2, and 5 if matched to S3. These numbers are not necessarily the ones you will face in any round of the experiment. However, if these numbers did exist then they would specify the cost to players of type S of being matched with any player of type U (matrix 1) and the value to any U−type player of being matched to a player of type S (matrix 2).

Experimental Procedures

The Laboratory Set Up

After you have finished reading these instructions you will be taken and placed in a classroom where you will be seated in two rows with S subjects sitting in front of U subjects. At your seat will be a sign indicating which subject you are an erasable pad and a marker. There will also be 10 envelopes. In each envelope will be a schedule listing your valuations (if you are a U−type subject) or cost (if you are a S−type subjects) for subjects of the opposite type. This is your private information, do not reveal it to anyone else. If you look at envelope 1 it will tell you the value (cost) schedule that you have for that round. You may only open the envelope relevant to the round you are in in the experiment−− you may not open envelopes relevant for future rounds. In front of the room will be a black board which will appear as follows:

S_1			S_2			S_3			Contracts
U_1	U_2	U_3	U_1	U_2	U_3	U_1	U_2	U_3	

This board will be used to record the bids made by the various U subjects for the subjects of the S type. For example, when subject U_1 makes a bid of say \$1.00 for subject S_2, the experimental administrator in the front of the room will place a 1 in the U_1 column under S_2. This will mean that subject U_1 has bid \$1.00 for subject S_2. As each new bid is made it will be written on the board for all subjects to see. Because of the way these bids will be recorded, they will be visible to all people in the room.

How to Make a Bid and A Contract

U–Type Subjects

At the beginning of each round all subjects will be asked to open their envelopes for that round and record the schedule there in columns 1–3 of the worksheet attached to their instructions. When we say begin, the round will start. After that point any U–type subject is free to make a bid for any S–type subject. (S type subjects will not be allowed to make any counter–offers). To do so he or she need only write the bid IN LARGE READABLE LETTERS on the pad placed at their seat and hold it above their head. An acceptable bid would be as follows: Say that U_3 wanted to bid \$2.00 for subject S_3. He or she would write the following on their sign:

S_3

2

The experimental administrator will then record your bid on the black board in front of the room by writing a 2 under the U_3 column under the label S_3. (You can wipe your pad clean by using the cloth supplied to you). As the bids come in form a given U subject, they are recorded on the board under each other. The last bid received in any column will be the only one that is active. Hence say you are subject U_1 and you have bid

2, .5, 1, and 3 for subject S_1 and that these have been recorded one under the other in the U_1 column under S_1' s label. Then at this moment, 3 will be the only one that S_1 can accept. Once it was received, it canceled all previous bids by U_1 for S_1. If a U–type subject wants to rescind all of his or her bids for any S–type subject, all they need to do is to write the word cancel and the subject ID number of whose bids they are canceling on their pad and hold it up. That will cancel all of their previous bids for that subject. For example, if U_2 wanted to cancel all of his bids for S_1, he could write the following sign:

CANCEL

S_1

If you want to go back to a bid you made previously, simply enter that bid again as if for the first time. For example, say you have bid .7, 1, and 2 for subject S_2. Since 2 was your last bid, it is the only one that is still available.Now say you want to re–enter your bid of .7. To do so simply write a sign that indicates that bid and hold it up. That will automatically re–enter your previous bid of .7 as soon as the administrator enters it on the board.

Note that there is no need for talking during the experiment. All communications will be done through cards and, in fact, talking of any type is strictly forbidden during the experiment.

S–Type Subjects

S–Type subjects will watch the blackboard and watch the bids that are made for them by the three U–type subjects. Once they see a bid from a U subject that they would like to accept, they will simply write on their pad the word ACCEPT and the

player whose bid they are accepting. For example, say that player S_2 wanted to accept U_1's last offer of \$3.00. He or she would then write:

ACCEPT

U_1.

It will be assumed that it is the bottom bid made by U_1 that is being accepted. The experimental administrator will then announce that a contract has been made between S_2 and U_1 and will write it, along with the price, on the right side of the board under the CONTRACTS label. (If two acceptances are made at the same time for a given U player's bid, the one chosen will be the one first recognized by the administrator. If they are both recognized simultaneously, a coin will be flipped and the contract made by chance). Bidding will then continue for the other S type subjects but note that once you have made a contract you are out of the market for the rest of the round. Each round will last 5 minutes. We will notify you when there are 2 minutes and 1 minute left and then count down from 10 seconds. If you can not make a contract in when the five minutes are up, your payoff for that round of the experiment will be zero.

Round Payoffs

If you are a U type player your payoff in any round will be your valuation for the player you have made a contract with (as given to you in the beginning of the round) minus the contract price that has just been accepted. If you are a subject of the S type your payoff will be your agreed upon contract price minus the cost to you of that U type player (as given to you at the beginning of the round).If you do not make a contract with any subject of the opposite type, your payoff will be zero for that round.

At the end of the round you will have to fill out the rest of your worksheet. As you see this worksheet asks you information about what you did during the experiment. For round 1 it asks you in column 4 to state by writing yes or no whether you made a contract during this period. If the answer is yes then in column 5 it asks you to record the identification number of the subject you made a contract with. If you made no contract leave this blank. In column 6, if you made a contract you should record the price of that contract. Finally in column 7 you are asked to record your payoff for that round. Remember, if you made no contract your payoff is 0. If you are a U−type subject and have made a contract your payoff is the difference between your valuation for the subject you contracted with and the price agreed on in your contract. If you are an S−type subject, your payoff will be the difference between the contract price and your cost for the subject you contracted with.

When this round is over you will you will proceed to the next round where you will have a new schedule of valuations (if you are a U−type subject) and costs (if you are an S−type subjects). You will find this schedule by opening the round 2 envelope in your package. Be sure that the schedule you are looking at is the relevant one for the round you are in in the experiment. We will announce each round out loud at the beginning of it so that you can check that you have the right schedule. Note then that since valuations and costs are changing, it will not generally be true that the subject you valued highly last round will still be the one you value highly this round.. All rules in this round will be identical to those explained above for round 1,(i.e., you will be given 5 minutes to make a contract with someone of the opposite type etc..) .

Final Payoffs

Your final payoffs will be derived by simply adding your payoffs up over the 10 rounds of the experiment. You will be paid this amount at the end minus $4.00.

CFA INSTRUCTIONS

General

This is an experiment in the economics of resource allocation. The instructions are simple and if you follow them carefully you might earn a considerable amount of money which will be paid to you at the end of the experiment. Funding for this experiment has been provided by various research foundations.

You will participate in a market lasting 10 rounds or market periods. At the beginning of the experiment, you will be assigned to be one of two type of players: denoted by U or S respectively. Your player type (U or S) will remain the same over all 10 periods. (Look at the upper right hand of your instruction sheet to see which type you are). The object of the market is to match yourself with a player of the opposite type and negotiate an agreement about the price of that match. That is, each S type player will attempt to form a match with one U–type subject and each U–type subject will attempt to form a match with one S–type subject.

In each period, there are 3 S players (S_1, S_2, S_3) and 3 U players (U_1, U_2, U_3). How much money you earn depends on which player of the opposite type you match yourself with and on the price determined for that match. How this price is determined is explained below.

How Your Earnings are Calculated

In each period you will be given a schedule. For U players, this schedule gives you the value of being matched with a specific S type. For S players, this schedule lists the cost associated with being matched with a specific U type. Note that you will receive a

new schedule at the beginning of each period. This schedule is your own private information, do not reveal it to anyone. For example, a player of type U might have the following schedule:

For Type U Players

Type U Valuations

Player	Value (in dollars)
S2	5
S1	2
S3	1

We read the schedule as follows. This U–type player gets 5 dollars if matched with player S2, 2 dollars if matched with player S1, and 1 dollars if matched with player S3. Your earnings for that period will be the stated value from your schedule, minus a "matching price". We will discuss how this matching price is calculated shortly. Hence, if this U–type is matched with player S3, his (her) payoff would be 5 dollars minus the price of the match. If that price is 1.5, the payoff is π = \$5 − \$1.5 = \$3.5. If a U player is not matched with an S player, then his(her) payoff for that period is 0.

For Type S Players

Type S Costs

Player	Cost (in dollars)
U2	3
U1	2
U3	1

We read the schedule as follows: This S type player must pay 3 dollars if he is matched with player U2, 2 dollars if matched with U1 and 1 dollar if matched with U3. This cost will then be subtracted from the matching price. Hence, if this player is matched with a player of type U1, his (her) payoff would be equal to the price of the match minus 2 dollars. If the matching price is \$2.5, then the payoff will be \$2.5 −\$2 =\$.5. If a S player is not matched then his(her) payoff for that period is 0. All you will know is your own values (cost) which will change in each period of the experiment.

Value–Cost Matrices

U players will always have one value of 5, one value of 4.5 and one value of 4, although the S players to whom these values are attached will change from round to round. S players will always have one cost of 2, one cost of 1 and one cost of .5 for U–type players, although the U players to whom these costs are attached will change from round to round. However, you will not know the schedule for any subject, but yourself. Based on the information given to you in each period, the value and cost of each person determines a pair of matrices. An example of such a pair is given below. By combining the schedules of each S and U player, we can construct value–cost matrices.

Matrix 1

Type–S Costs

	S1	S2	S3
U1	.5	.5	2
U2	2	1	1
U3	1	2	.5

Matrix 2

Type–U Values

	U1	U2	U3
S1	4.5	5	5
S2	4	4.5	4
S3	5	4	4.5

These matrices are read by looking down the columns. For example, looking down the second column in matrix 1, we see that the cost to player S2 will be .5 if matched with

player U1, 1 if matched with player U2, and 2 if matched with player U3. Looking down column 1 in matrix 2, we see that the value of a match to U1, is 4.5 if matched with S1, 4 if matched with S2, and 5 if matched to S3. These numbers are not necessarily the ones you will face in any round of the experiment. However, if these numbers did exist then they would specify the cost to players of type S of being matched with any player of type U (matrix 1) and the value to any U–type player of being matched to a player of type S (matrix 2).

Experimental Procedures

After you have finished reading these instructions you will be taken and placed in the office of a Professor in the Economics Department. On the desk where you will sit will be a list of phone numbers along with 10 sealed envelopes. In each envelope will be a schedule listing your valuations (if you are a U–type subject) or cost (if you are a S–type subjects) for subjects of the opposite type. If you look at envelope 1 it will tell you the value (cost) that you have for that round. You may only open the envelope relevant to the rounf you are in in the experiment–– you may not open envelopes relevant for future rounds. If you are an S–type subject the telephone numbers will be those of the U–type subjects and if you are a U–type subject the telephone numbers will be those of the S–type subjects. You will also be told the identification number of these subjects which you will need for the purpose of making contracts. Each market period or round will last for 5 minutes and during that time you will be free to call up whomever you want of the opposite type and try to make a deal. In your discussions you can say what you wish but you can not threaten the person you are talking with, nor can you make plans for payments outside of the experiment when it is over. For example, a statement like "Listen,

lets agree on price z and after the experiment I will give you $5.00" is not allowed and if heard by an experimental administrator will disqualify you from the experiment. You will also not be allowed to make contracts for any round except the one you are currently in. We will announce when there are 4,3,2,and 1 minutes left in the round, and will also announce the 30 second mark. We will then count down from 10 seconds until the round is over. If in your negotiations you and someone you have been talking with come to an agreement, you should take your phone off of the hook and signal to an experimental administrator who will be waiting outside of your door. Tell him the number of the subject with whom you have made a contract and the "match price" you have agreed on. He will then bring a contract sheet for you to sign. If you and your contracting party both agree on the price and sign the sheet, the contract will be binding and your participation in this round of the experiment will be over. (Once you make a contract in a round, you may no longer call anyone else for the remainder of that round, and you must keep your phone off of the hook. We will announce the formation of each contract (but not their price) as they are formed so that you will know who is out of the market. If you are a U type player your payoff will be your valuation for the player you have made a contract with (as given to you in the beginning of the round) minus the "match price". If you are a subject of the S type your payoff will be your agreed upon "match price" minus the cost to you of that U type player (as given to you at the beginning of the round).If you do not make a contract with any subject of the opposite type, your payoff will be zero for that round.

At the end of the round you will have to fill out the worksheet that is attached to these instructions. As you see this worksheet asks you information about what you did during the experiment. For round 1 it asks you in column 1 to list your valuation or cost schedule for that round. In column 2 it asks you to record the identification numbers of all subjects you spoke with. Finally, in column 3 it asks you to state by writing yes or no

whether you made a contract during this period. If the answer is yes then in column 4 it asks you to record the identification number of the subjects you made a contract with. If you made no contract leave this blank. In column 5, if you made a contract you should record the price of that contract. Finally in column 6 you are asked to record your payoff for that round. Remember, if you made no contract your payoff is 0. If you are a U−type subject and have made a contract your payoff is the difference between your valuation for the subject you contracted with and the price agreed on in your contract. If you are an S−type subject, your payoff will be the difference between the match price you negotiate and your cost for the subject you contract with. At the end of each round we will send you a sheet listing who made contracts with whom and at what price.

When this round is over you will you will proceed to the next round where your will have a new schedule of valuations (if you are a U−type subject) and costs (if you are an S−type subjects). You will find this schedule by opening the round 2 envelope in your package. Be sure that the schedule you are looking at is the relevant one for the round you are in in the experiment. We will announce each round out loud at the beginning of it so that you can check that you have the right schedule. Note then that since valuations and costs are changing, it will not generally be true that the subject you spoke with or contracted with last period will have the same value or cost this period. All rules in this round will be identical to those explained above for round 1,(i.e., you will be given 5 minutes to make a contract with someone of the opposite type etc..) . We will have 20 rounds in the experiment.

Final Payoffs

Your final payoffs will be derived by simply adding your payoffs up over the 10 rounds of the experiment. You will be paid this amount at the end plus $3.00 which we pay you simply for showing up.

Name
Subject I.D.
Time
Date
Group

Round 1 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 2 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 3 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 4 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 5 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 6 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 7 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff
Round 8 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff

Round 9 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff

Round 10 Valuation S_1 S_2 S_3	Subject Talked to (List ID #)	Did you form a contract?	if yes, with whom was it formed? (ID#)	Price	Payoff