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A PRACTICAL PERSON'S GUIDE TO MECHANISM SELECTION: SOME LESSONS FROM EXPERIMENTAL ECONOMICS

BY

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ABSTRACT

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One of the most interesting developments in economic theory over the past twenty years has been the emergence of the theory of mechanism design. In short, mechanism design theory investigates whether it is possible to design an economic institution (represented formally as a game form) which, when imposed upon a set of individualistic agents, will lead them to take actions consistent with some a priori chosen performance (social welfare) criterion.

In the real world, however, mechanisms compete for adoption. By this I mean that for any given allocation problem an organization might face, there might be a number of mechanisms available to solve it. The organization's leaders must then choose between these mechanisms based on their characteristics and if, for example, the mechanisms have different distributional consequences for the power groups within the organization, a political battle may ensue with each power group lobbying for the adoption of their own mechanism. The mechanism that is ultimately chosen will emerge from this bargaining process within the organization. The process of **mechanism design** is therefore different from the process of **mechanism selection**.

In this paper we concern ourselves with the selection criteria that organizations might use to choose between mechanisms. It is called a practical person's guide because the criteria I will be discussing are not the elegant criteria used by economic theorists to justify their mechanisms but rather the criteria likely to be used by some no-nonsense corporate C.E.O. or government official. Seven criteria are offered which we think are reasonable ones to be considered when the mechanism selection problem arises. Evidence from a number of experimental studies is then offered to evaluate these criteria using the mechanisms investigated by these experimental studies.

A PRACTICAL PERSON'S GUIDE TO MECHANISM SELECTION: SOME LESSONS FROM EXPERIMENTAL ECONOMICS

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Section 1: Introduction.

One of the most interesting developments in economic theory over the past twenty years has been the emergence of the theory of mechanism design. Starting with the pioneering work of Hurwicz (1972), this theory has become increasingly rich in detail and analysis. (For a wonderful survey of the field see Moore (1993)). In short, mechanism design theory investigates whether it is possible to design an economic institution (represented formally as a game form) which, when imposed upon a set of individualistic agents, will lead them to take actions consistent with some a priori chosen performance (social welfare) criterion. For instance, an early question arose as to whether it is possible to design a mechanism for the allocation of public goods which will lead economic agents to reveal their true preferences for the public good as a dominant strategy equilibrium to the game defined by the mechanism. This question was answered in the affirmative by Theodore Groves (1973) in his famous article "Incentives in Teams". Other such examples are easy to offer.

In the real world, however, mechanisms compete for adoption. By this I mean that for any given allocation problem an organization might face, there might be a number of mechanisms available to solve it. The organization's leaders must then choose between these mechanisms based on their characteristics and if, for example, the mechanisms have different distributional consequences for the power groups within the organization, a political battle may ensue with each power group lobbying for the adoption of their own mechanism. The mechanism that is ultimately chosen will emerge from this bargaining process within the organization. The process of **mechanism design** is therefore different from the process of **mechanism selection**. Mechanisms that seem natural to a well trained economist may strike real world decision makers as bizarre. The reason for this difference is that the criteria by which we economists judge economic institutions is quite different from those used by real world decision makers. This is the prime reason why so few of our theoretically elegant mechanisms have actually been adopted for use.

In this paper we concern ourselves with the selection criteria that organizations might use to choose between mechanisms. I have called this a practical person's guide because the criteria I will be discussing are not the elegant criteria used by economic theorists to justify their mechanisms but rather the criteria likely to be used by some no-nonsense corporate C.E.O. or government official.

In the remainder of the paper I will proceed as follows. In the Section 2 I will outline and discuss the criteria I have found relevant for the mechanism selection decision. Some of these criteria I have discovered by speaking to corporate leaders while others I have simply dreamed up myself. I will let you guess which is which. In Section 3 I will offer some experimental results which demonstrate some of the properties listed in Section 2. In this section I will rely heavily on my own work much of which was done jointly with Roy Radner. My egocentric bias here is justified only on the basis of the fact that these are the works I am most familiar with and with which I have the raw data necessary to present some of the calculations required to make my point. There are obviously many other works that could be used as well. Finally, in Section 4 I offer some comments and conclusions.

Section 2: Selection Criteria

There are many criteria which should be met by an allocating mechanism before an organization would consider using it 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. 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 is suggested, 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 when using it. A more demanding criterion would require that the participants understand the theory underlying the mechanism. However, it is rare that the theory underlying a mechanism is included in the user's manual for that mechanism when it is distributed to the general population for use. (The IRS while distributing tax tables, never distributes journal articles on optimal income taxation to citizens or tips on how to exploit the loopholes in the law.)

Understandability is obviously essential since confusing mechanisms may be badly misinterpreted by the agents using them and may lead to behavior that is totally unexpected and detrimental to the profitability of the organization. Some times a mechanism is perceived as being more understandable if it can be couched in a metaphor that is familiar to the agents. For example, since at least in the United States we are inculcated with the jargon of competitive markets, mechanisms in which people place bids and goods are allocated by something resembling prices may be easier for agents to comprehend than mechanisms requiring more abstract messages like preference orderings. Hence, they are likely to be taken more seriously as candidates for adoption.

2) Fairness-- Strategic Symmetry

If a mechanism is ever going to be employed it must be perceived as being "fair". We call a mechanism "fair" if it is strategically 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 outcomes that result may, of course be unequal, but that may be an artifact of the types of preferences the agents have. (A double-oral auction mechanism is fair because both sides are treated symmetrically. Prices may be skewed to favor one side of the market simply because the other side have high willingnesses to pay (or low costs).) Our emphasis on the symmetry of the strategy sets of agents is motivated by the fact that economic agents, when presented with a mechanism, judge it to a large extent by the rules and if one side is offered strategies that the others can not avail themselves of, a red flag is automatically raised.

There are a number of reasons why perceived equity might be important. First, in many industries a mechanism must be agreed upon by all parties involved in trade. For example, in many labor negotiations if talks are stalemated, some type of arbitration is resorted to. Many different arbitration mechanisms exist, however, including final offer arbitration, Tri-offer arbitration (see Ashenfelter (1992)), just to mention a few. Not all schemes are equivalent with respect to how they treat the bargaining parties however, and if each side has a veto on the matter, no arbitration mechanism which systematically favors one side will be likely to be chosen.

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. Further, in addition to the overall efficiency of a mechanism the manner in which that efficiency is determined may be important. For instance, it is possible to have a set of mechanisms all of which are close to being second-best efficient but which achieve this efficiency in different ways. For example, consider a set of different bargaining mechanisms each of whose purpose is to consummate deals between buyers and sellers in an incomplete information environment. In such situations, buyers have only probabilistic information about the costs of sellers who have only probabilistic information about the values of buyers. However, instead of having one buyer and one seller who could be of different types, let us assume that there are many buyers and many sellers who will be matched pair-wise and asked to bargain. At a first best outcome, all trades for which there are positive gains from trade should be made and those buyers and sellers should consummate deals. As we know, while no mechanism can achieve such first best outcomes, given the incomplete information described above, mechanisms achieving or approaching second-best results are sometimes available.

But near second-best outcomes could be achieved in several ways. One mechanism might make all of the very profitable trades available (i.e. trades between high value buyers and low cost sellers) but miss a large number of trades on which the gains are small. Another mechanism might miss a few big and profitable trades, but be much better in being successful on the small-gain trades. If the ex poste efficiencies of these two mechanisms are comparable, which is chosen will depend on how exactly these efficiencies are determined. For example, if there are relatively many more small-gain situations than large gain ones, the cries of small-gain traders may well drown out those of the large-gain traders. Put differently, since high cost sellers and low value buyers are most likely to be in situations in which the gains from trade are small, they are more likely to prefer that mechanism which makes a majority of the small-gain trades. Again, despite the equality in the over all efficiencies the composition of these gains may be important.

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, one could not consider a mechanism as satisfactory, if despite its ability to implement Pareto-optimal outcomes at a Nash equilibrium, it produces disastrous outcomes for reasonably small mistakes (say mistakes larger than mere trembles) or deviations. In essence, we are talking here about the shape of the efficiency surface of the mechanism around the Nash equilibrium point and asking that it be flat.

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 mechanism are greatly influenced by the personalities actual people who use it, we can expect a larger than usual variance in outcomes and a greater sense of uncertainty about the mechanism's outcomes. For instance, assume that a mechanism implements Pareto optimal outcomes but the exact outcome on the Pareto surface that is chosen depends on how the game defined by the mechanism is actually "played" (i.e., different players might select different equilibria). Since we can think of organizations as infinitely lived entities, any choice of a mechanism commits the players to a game to be played by yet unknown fiduciaries in the future. If the outcomes are sensitive to the play of these yet unknown agents, the choice of a mechanism today may expose future agents of one's type to dismal outcomes. A mechanism which is not personality robust would therefore be a risky choice and therefore be rejected by a risk averse agent today.

6) Agent Profitability

New institutions are never imposed in a 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, take the process of wage determination in the professional baseball industry. In this industry we have a set of agents who have historically played an active role in the wage setting process. These include the team owners, the players association, the players themselves and the lawyers of the players. In addition, salaries have been set by negotiation. This industry, however, is one desperately in need of a new salary determination mechanism since both sides are dissatisfied with the outcomes of the current "free-agent" system. However, any new mechanism which does not provide a profitable role for the current set of agents (i.e. for the lawyers of the players) is likely to be rejected since no lawyer is likely to endorse a system which eliminates his or her future rents.

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.

Section 3: Experimental Evidence

In this section of the paper I will review the results of a number of different experimental studies. Each study is presented in an effort to highlight how the mechanisms examined there satisfies the criteria specified in Section 2.

3.1: Personality Robustness and Efficiency: The Sealed-bid Mechanism vs. Face-to-Face Bargaining in Incomplete Information Environments.

Consider the following bargaining mechanism that can be used to structure bargaining between two economic agents say, for example, between two profit centers within a large scale organization. Assume that a potential buyer, B, and a potential seller, S, are bargaining over the terms of a possible trade of a single object. If the object is traded, the value to B is V and the cost to S is C. (The seller incurs no cost if there is no trade.) The sealed-bid mechanism works as follows: B and S simultaneously choose bids, v and c, respectively. If $v \geq c$, then the trade takes place, and B pays S the price $P = (v+c)/2$, i.e. the average of the two bids. If $v < c$, then no trade takes place and B pays S nothing.

Suppose that at the time of bidding, B knows V but not C, and S knows C but not V. The situation is modelled by supposing that V and C are random variables with a joint probability distribution called the prior, which is known to both parties. For the experiments discussed below we will assume that the values and costs of the buyers and sellers are drawn independently from the closed interval [0,100] using distributions with the following cdf's:

$$F(V) = 1-([1-V/100])^{r_1},$$

$$G(C) = (C/100)^{r_2}.$$

By varying r_1 and r_2 from 0 to 1, we can move these distributions from the perfect certainty case (r_i = 0) to the case of a uniform distribution (r_i = 1.0). When $r_1 = r_2$ we will call the mechanism "symmetric", while when $r_1 \neq r_2$, the mechanism is "asymmetric". Before the bidding takes place, B observes V but not C, and S observes C but not V. B's strategy is a function β that determines his bid v for each value of V, and S's strategy is a function γ that determines his bid c for each value of C. Thus

$$\begin{aligned} v &= \beta(V). \\ c &= \gamma(C). \end{aligned} \tag{3.1}$$

The buyers' and sellers' profits are, respectively,

$$\phi_B = \begin{cases} V - \dfrac{(v+c)}{2} & V \geq c, \\ 0 & v < c, \end{cases} \tag{3.2}$$

$$\phi_S = \begin{cases} \dfrac{(v+c)}{2} & V \geq c, \\ 0 & v < c, \end{cases} \tag{3.3}$$

Suppose that the parties are risk neutral, so that, for a given pair of strategies, β and γ, the expected utilities are

$$\pi_B(\beta,\gamma) = E\ \phi_B$$

$$\pi_S(\beta,\gamma) = E\ \phi_S$$

where the expectation is taken with respect to the prior distribution of V and C. Equations (1.1) - (1.3) determine a non-cooperative game. As usual, an equilibrium of the game is a pair of strategies such that neither player can increase his expected utility (expected profit) by unilaterally changing his strategy.

If F and G are uniform distributions ($r_1 = r_2 = 1.0$) defined over the closed interval [0,100], then as Chatterjee and Samuelson [1983] have demonstrated, there exists a pair of linear bidding strategies which together form an equilibrium of the game defined by the sealed-bid mechanism. These strategies are as follows:

$$v = \begin{cases} V & V < 25\ , \\ \frac{25}{3} + \frac{2}{3}V & V \geq 25 \end{cases}$$

$$c = \begin{cases} C & C > 75\ , \\ 25 + \frac{2}{3}C & C \leq 75, \end{cases}$$

At the equilibrium, the buyer bids his value for all realizations less than 25, but under-bids for all realizations above that value, while the seller bids his cost for all realizations greater than 75, and overbids for all realizations below that value.

Myerson and Satterthwaite [1983] have demonstrated that this particular equilibrium has a very strong welfare property: It maximizes the ex ante gains from trade that can be achieved at any Bayesian-

Nash equilibrium of any individually rational bargaining mechanism employed in this environment, in which what the seller received equals what the buyer pays.

There are other equilibria to this mechanism as Leininger, Linhart, and Radner [1989] and Satterthwaite and Williams [1989] have shown. In fact there are an infinite number of other such equilibria, some of which involve continuous but non-linear bid functions and some of which involve discontinuous step-functions.

In the theory of bargaining under incomplete information quite a bit of attention has been focused on the sealed-bid mechanism mostly because of the Myerson-Satterthwaite result that the linear equilibrium of this mechanism is the only equilibrium of any mechanism capable of achieving second-best welfare results.

In a set of experiments, Radner and Schotter (1989) test the sealed bid mechanism and found that, at least in the laboratory, it performed as well or in some cases even better than the theoretical prediction. (This result was replicated by Rapoport and Fuller (1992) in a slightly different design.) More precisely, they found that subjects did, in fact, tend to use linear bidding strategies and as a result were capable of achieving efficiencies that were at least equal to second-best optimal efficiencies.

Since theory tells us that the linear equilibrium of the sealed-bid mechanism is the only one capable of achieving these efficiencies and laboratory experience supports this contention, it would appear that our search for an optimal way to structure bargaining is over. Ironically, however, simple unstructured face-to-face bargaining does even better. That is, for bargaining situations the mechanism in which people simply sit face to face and bargain with each other in an unstructured manner appears capable of achieving almost first-best gain from trade. Evidence for this laboratory stylized fact is born out by experiments on Coasian bargaining performed by Hoffman and Spitzer (1982) and others, in a complete information context, and by the face-to-face bargaining experiments of Radner and Schotter (1989) where face-to-face bargaining seemed to be remarkably efficient in attaining first-best gains from trade in incomplete information bargaining situations. Anonymous procedures like those of Roth and Murdigham (1982), where bargainers communicate in a virtually unrestricted manner through computer terminals, were less successful. These results led Radner and Schotter (1989) to comment that:

"The success of the face-to-face mechanism, if replicated, might lead to a halt in the search for better ways to structure bargaining in situations of incomplete information. It would create, however, a need for a theory of such unstructured bargaining in order to enable us to understand why the mechanism is so successful" (Radner and Schotter (1989, p.210)).

From the description of these results it is obvious that we have a **mechanism selection** problem here since we are faced with a problem (how to structure bargaining within an organization) and two competing mechanisms that can be used to solve it -- the sealed bid mechanism and the face-to-face bargaining mechanism. Which one should we choose? It is at this point that the criteria which we specified in Section 2 come into play. On many of the criteria there are no real differences between these two mechanisms. For example, both are easily understandable and fair in the sense that the rules treat each agent in a strategically symmetrical manner. As we will see later when we review the Linhart, Radner, Schotter (1993) paper, on both a theoretical and an empirical level the sealed-bid mechanism is strategically robust in the sense that its efficiencies are relatively high and invariant to considerable deviations of the bidding strategies of subjects away from truth-telling. From the small face-to-face bargaining experiment run by Radner and Schotter (1989) face-to-face bargaining also seems to be a robust mechanism in that it almost always leads to efficiencies close to the first best levels. Theoretically it is, of course, not possible to say anything about unstructured face-to-face bargaining since one can not write down the game form describing it. The big differences between the mechanisms pertains to the efficiency and personality robustness criteria.

On efficiency grounds face-to-face bargaining seems to dominate the sealed bid mechanism. To illustrate this point let us look at Table 1.

Table 1
Disagreement and Inefficiency Rates

		Disagreement Rate (%)			Inefficiency Rate (%)		
Experiment Type	Number of Observations	1st 7 rounds	Last 8 rounds	Total	1st 7 rounds	Last 8 rounds	Total
Face-to-Face	150	6	6	6	1	1	1
Sealed Bid Bargaining	150	25	32	30	13	14	13

In this table we assess and compare the performance of the sealed-bid and face-to-face bargaining mechanisms using various measurements of **inefficiency**, or the failure to realize potential gains from trade when these potential gains are positive.[1] The potential gains from trade for a particular round are the difference between the value **V** to the buyer and the cost **C** to the seller. Provided that the value exceeds the cost, any price **P** such that **C** < **P** < **V** would generate positive profits for both parties. One way of measuring the inefficiency of a bargaining experiment is the **disagreement rate**: the ratio of the number of rounds in which no agreement was reached despite positive potential gains from trade, to the total number of rounds in which potential gains were positive. An alternative measure, which we call the **inefficiency rate**, is the ratio of the sum of unrealized positive potential gains from trade to total positive potential gains. As we see from Table 1, both in terms of inefficiency and disagreement rates, face-to-face bargaining outperformed the sealed-bid mechanism. While the sealed-bid mechanism was able to capture 87% of the first-best gains from trade, face-to-face bargaining captured nearly 99%

Where the face-to-face mechanism failed is in the variance of the payoffs to the players and the prices formed. The face-to-face mechanism determined payoffs which varied greatly across experimental bargaining pairs as did the prices formed. For example, while the mean payoff to a buyer (seller) in the

1 In both experiments the prior distribution had coefficients $r_1 = 0.4$ and $r_2 = 0.4$.

face-to-face experiment was 30.53 (28.88), the variance around those means was 502.93 (561.33) respectively. For the sealed bid mechanism the mean payoffs were 32.49 (35.79) respectively for buyers and sellers while the variance around these means were 270.45 (352.27). In short the variability of payoffs and prices was around 30% smaller in the sealed-bid mechanism when compared to the face-to-face mechanism. The histograms of these payoffs are presented in Figures 1a and 1b.

Figures 1a and 1b

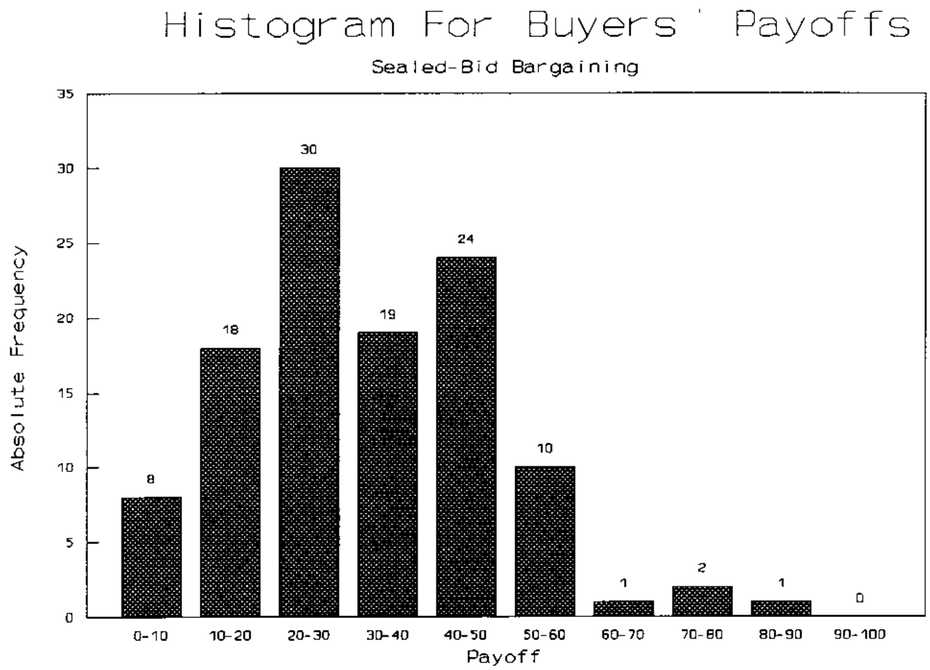
Note that the distribution of buyer and seller payoffs are far more spread out in the face-to-face bargaining experiment than they are in the sealed-bid mechanism. A similar result can be seen in the price data as portrayed in Figure 2.

Figure 2

From this data we conclude that while both mechanisms may be robust in the strategic sense, the face-to-face bargaining mechanism is not robust to the personalities using it. What this means is that when two people face each other in face-to-face bargaining, while the outcome is likely to be efficient, the distribution of gains to trade and the prices formed are likely to be widely dispersed and dependent on the personalities of the people doing the bargaining. This has a number of consequences. First, it implies that for reasons of risk aversion, the sealed-bid mechanism may be preferable to the face-to-face mechanism since although it has a lower mean efficiency, the payoff to any one side using the mechanism has a smaller variability. Second, since bargaining in the future is likely to be done by agents unknown to today's principals, decision makers may want to opt for the security of a mechanism that protects them from the variability introduced by not knowing what agents will use the mechanism in the future. This

Figure 1

(A)


Histogram For Buyers' Payoffs
Sealed-Bid Bargaining
Absolute Frequency
Payoff
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
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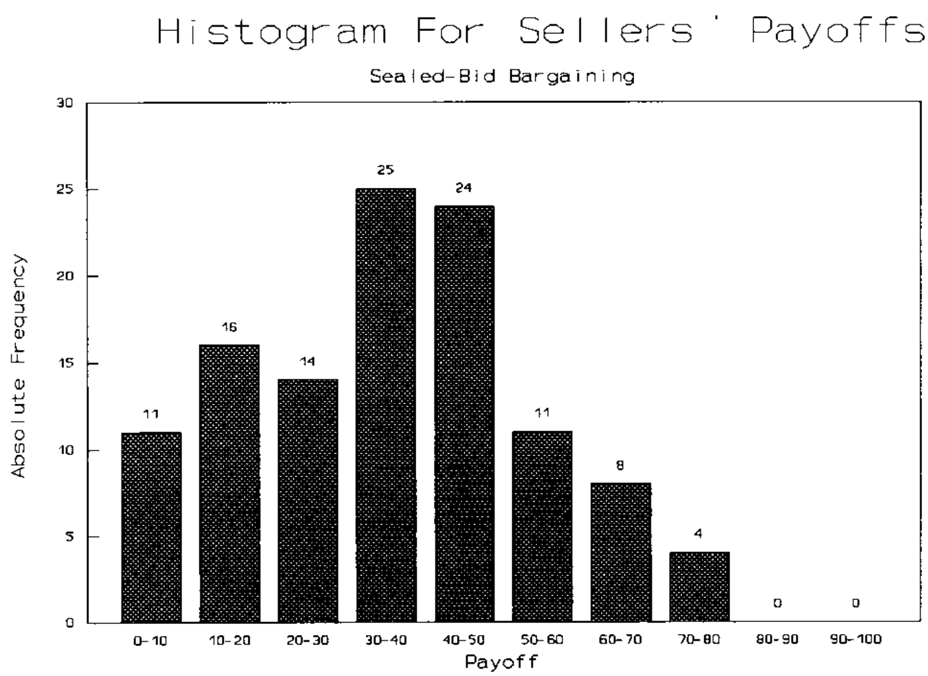
Histogram For Sellers' Payoffs
Sealed-Bid Bargaining
Absolute Frequency
Payoff
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
11
16
14
25
24
11
8
4
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0
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5
10
15
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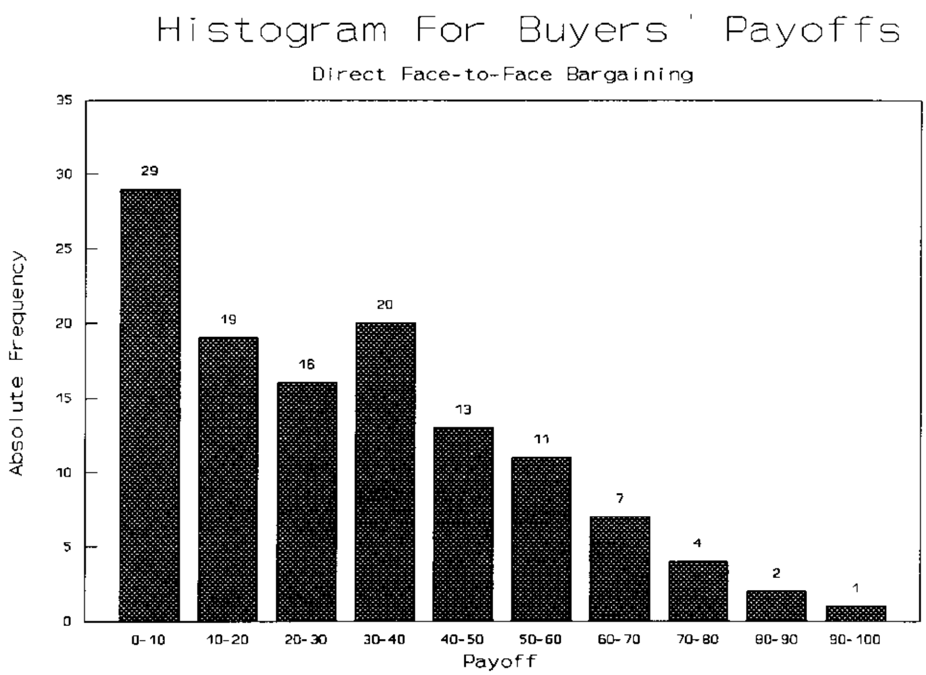
25
30

(B)


Histogram For Buyers' Payoffs
Direct Face-to-Face Bargaining
Absolute Frequency
Payoff
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5
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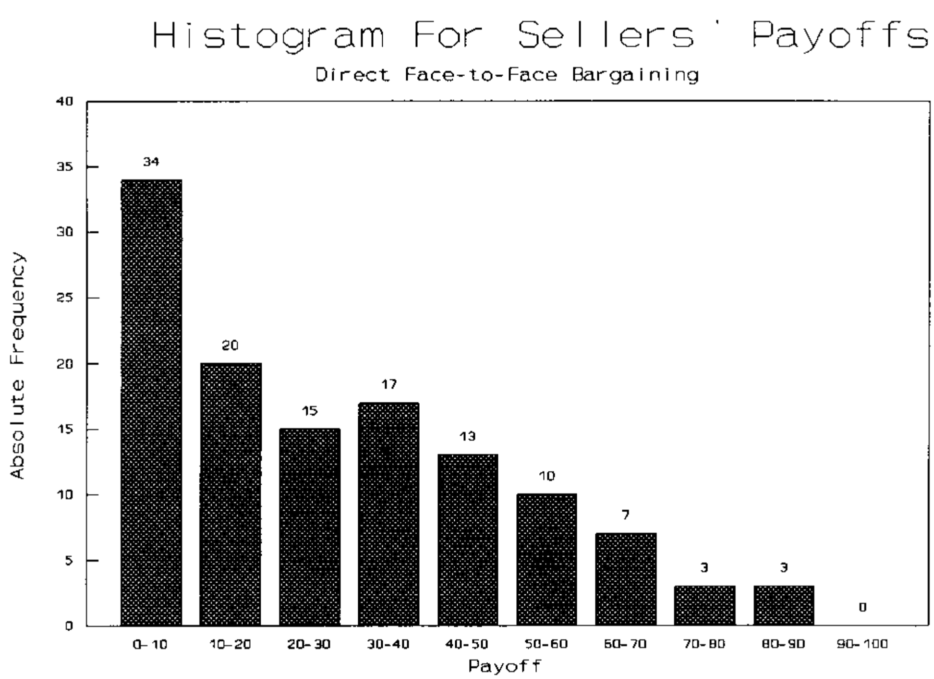
Histogram For Sellers' Payoffs
Direct Face-to-Face Bargaining
Absolute Frequency
Payoff
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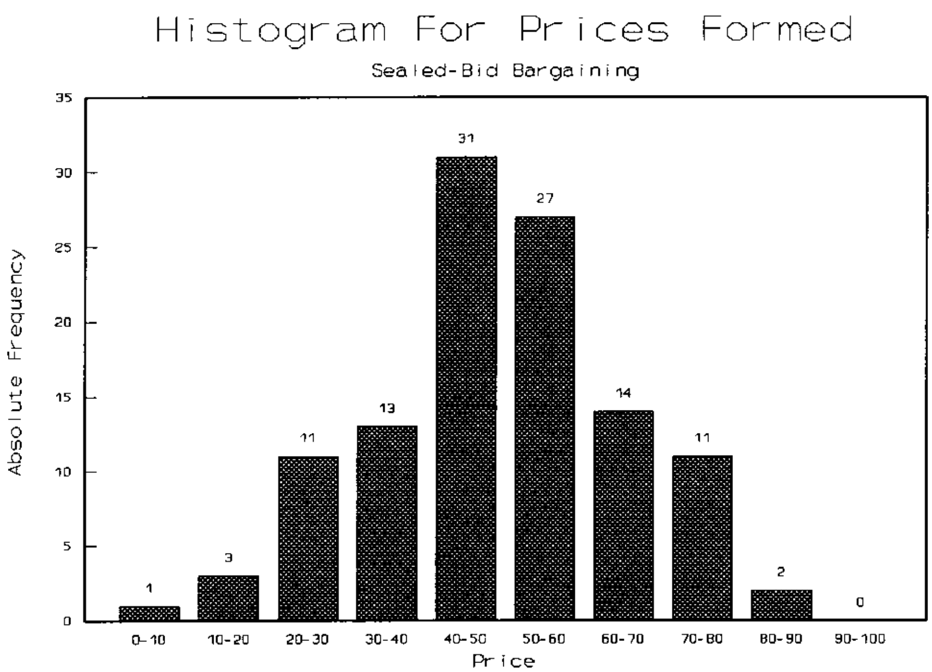
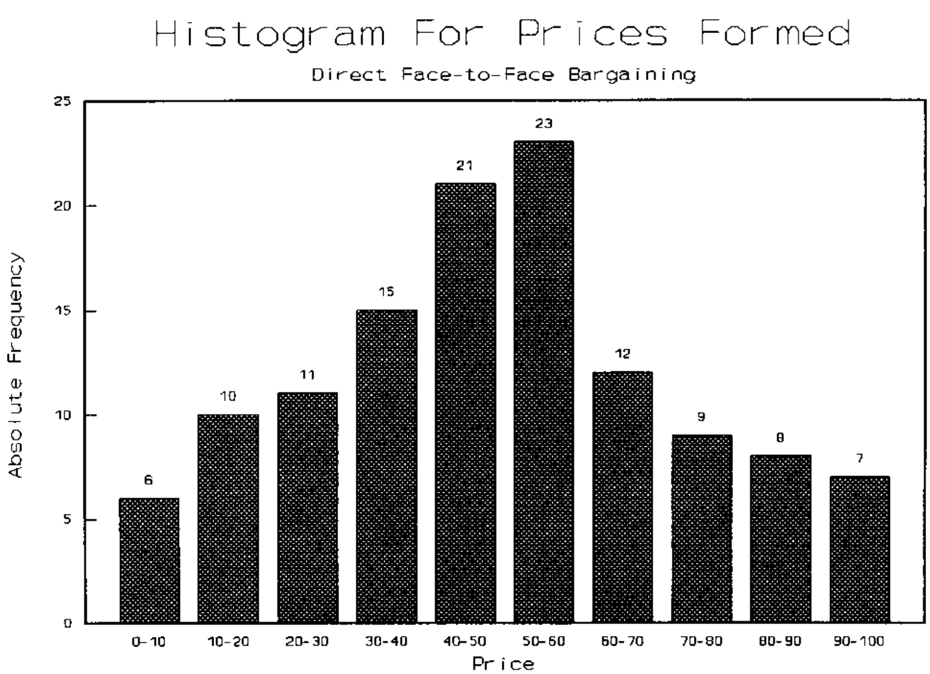
Figure 2

(A)



Histogram For Prices Formed
Sealed-Bid Bargaining
Absolute Frequency
Price
0 5 10 15 20 25 30 35
1 3 11 13 31 27 14 11 2 0
0-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100

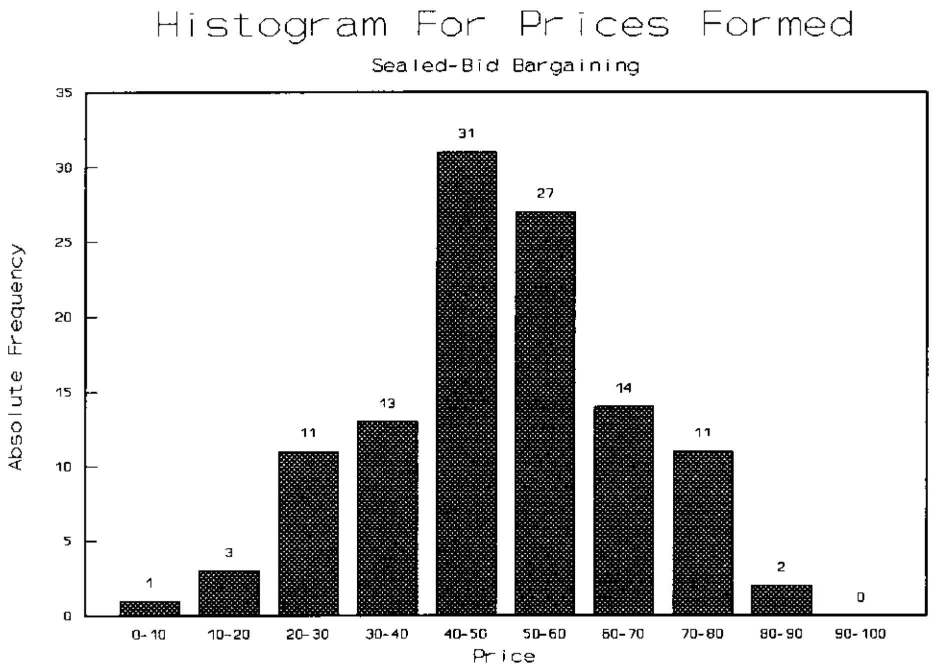
(B)



Histogram For Prices Formed
Direct Face-to-Face Bargaining
Absolute Frequency
Price
0 5 10 15 20 25
6 10 11 15 21 23 12 9 8 7
0-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100

Figure 2

(A)


Histogram For Prices Formed
Sealed-Bid Bargaining
Absolute Frequency
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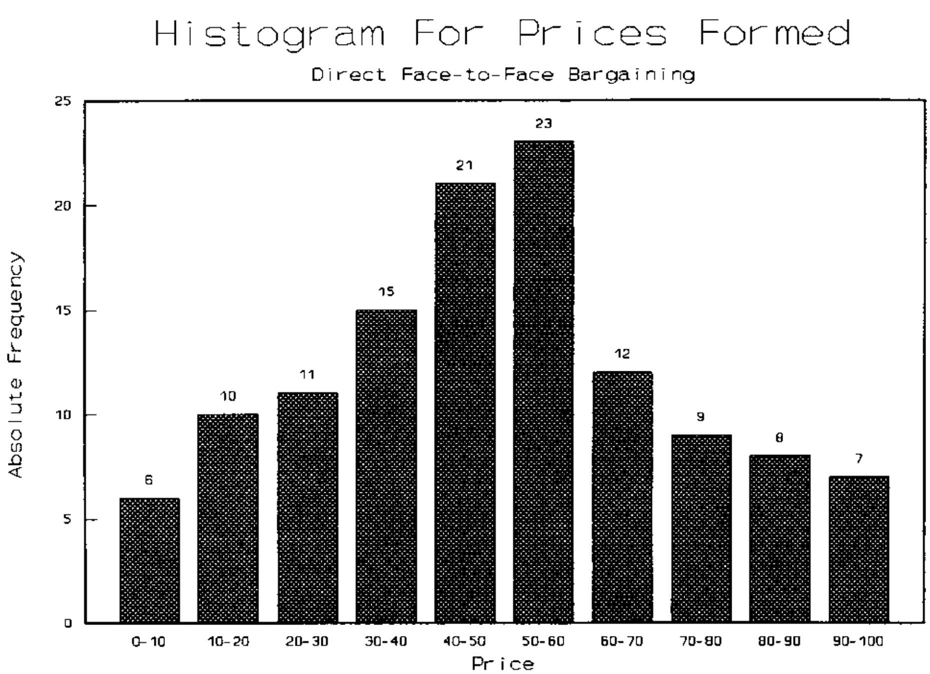
80-90
90-100
Price

(B)


Histogram For Prices Formed
Direct Face-to-Face Bargaining
Absolute Frequency
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12
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20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
Price

is the essence of personality robustness.

Which one of these two mechanism will ultimately be chosen in an organization forced to consider them only, can obviously not be determined without knowing the preferences of the decision makers over efficiency and the variability introduced by personality non-robustness. Still, I hope that this example at least introduces the problem of mechanism selection .

3.2: Mechanism Selection in the Baseball Industry: A Comparison of Three Mechanisms

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 team 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 was recently contested and found to be 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 Nalbantian and Schotter (1990) 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 they felt 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, they investigated 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.

3.2.1: 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" where the object of analysis is a matching algorithm which will permit the matching of people to people like the matching of men and women into monogamous marriages.

The Experiments and Experimental Design

Three sets of experiments were conducted by Nalbantian and Schotter (1990) each aimed at replicating the salient features of a different allocation mechanism and evaluating their performance.

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 them 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[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 at most 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-

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.

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:

Matrix 1: U-Type Preferences

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

Matrix 2: 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 1) or cost (matrix 2) 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

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.

$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 other 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.

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.

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.

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 the following pair of linear programs were solved using the bids submitted as information.

I

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

s.t.

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

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

where

x_{ij} is the intensity with which we match subjects i and j,[4]

b_{ij} is the bid entered by U-type subject i for S-type subject j,

c_{ji} is the bid entered by S-type subject j for U-type subject i,

II

Min $\Sigma_{ij}(p_{ji}-c_{ji})$

s.t.

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

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

$\Sigma_i M_i + \Sigma_{ij}(p_{ji}-c_{ji}) = V.$

where

M_i is a fee that must be paid by U-type subject i to participate in the market,

p_{ji} is the price for S-type subject j charged to U-type subject i and,

V is the optimal value of the primal problem I.

Problem I matches S-types and U-types in an optimal (surplus maximizing) manner and always contains an integer solution, while problem II finds a set of prices which support this optimal matching. In fact problem II finds that set of prices p_{ji} which are the lowest competitive prices supporting the optimal match. M_i is a fee which can be set to differentially split the rent or surplus created by the matches.

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 $[p_{ji,}p_{ji} + M_i]$. In

4One can think of U-types and S-types as possessing one unit of time to be allocated across different matches. Hence x_{ij} is the fraction of time that U-type i and S-type j will spend together in match ij. The constraints indicate that no S- or U-type can have more than one unit allocated to all matches they are in.

short, the linear program determines a matching and a range within which to negotiate a price. Because price setting in this mechanism requires some bargaining, Nalbantian and Schotter did not want to disrupt the experiment after each round and allow subjects to bargain. Hence they 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[5]

3.2.3: Some Preliminary Results

On the basis of the experiments performed Nalbantian and Schotter 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

5This 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.

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.

2.4 The Mechanism Selection Criteria and Our Three Mechanisms

These experiments present yet another example of the mechanisms selection problem. Three mechanisms (the CFA the CM and the SM) are all competing for selection by the baseball industry. Let us see how these three mechanisms do when measured by our criteria:

Understandability

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.

Fairness-- Strategic Symmetry

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.

Efficiency

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.

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.

Personality Robustness

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.

Agent Profitability

In the baseball industry there are 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.

Collusion Freeness

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.

3.3 The Sealed Bid Mechanism: A Strategically Robust Mechanism

In reviewing the results of a set of experiments (Linhart, Radner and Schotter - henceforth LRS - 1990) on sealed-bid bargaining with incomplete information, they (the authors) were struck by the robustness of the results. By "robustnss" they meant that although the subjects used a wide variety of bargaining strategies, and although the bargainers' strategy pairs were not best responses to each other, still the achieved efficiencies were nevertheless quite high, and clustered in a fairly narrow range, about 80-90%. (By "efficiency" we here mean total gains from trade as a fraction of first-best (truth-telling) gains from trade.) Moreover, this robustness was observed for nine different pairs of distributions (priors) of the bargainers' beliefs as to their opponents' true types. To illustrate this point they show the average efficiencies achieved by their subjects as a function of r_1 and r_2, in Table II, both for the last 25 rounds and for all 75 rounds. One sees a slight but consistent increase in the last 25 rounds; perhaps this is related to learning. On the other hand, the preference for linear strategies of truth-telling when r_1 = r_2 = 1 has not resulted in increased efficiency.

75 rounds

		r_1		
		1	0.4	0.2
r_2	1	.831	.845	.833
	0.4	.856	.854	.785
	0.2	.810	.887	.822

Overall average : 0.836

Range: 0.102

Last 25 rounds

		r_1		
		1	0.4	0.2
r_2	1	.832	.842	.845
	0.4	.894	.864	.8652
	0.2	.890	.897	.858

Overall average : 0.865

Range: 0.065

Table 2: Efficiencies (Aggregated over strategy classes)

These are not the most striking features of the results, however. What is most striking is that the average efficiencies are bunched between 80% and 90%, that is in the range of the efficiencies of linear equilibria, and are essentially independent of the priors (i.e. of the values of r_1 and r_2). It is this robustness of efficiency that is so appealing since if it is a true feature of the sealed-bid mechanism it might make it a reliable provider of almost-second-best results.

We have also examined the average profits of the buyer and seller. These are shown in Table 3, for all 75 rounds, and in Table 4 for the last 25 rounds. What are tabulated are average profits as a fraction of first-best gains from trade, for each (r_1, r_2) pair. Thus is both bargainers had always bid their true values, every entry in these tables would have been 0.5.

Buyers

		r_1		
		1.0	0.4	0.2
r_2	1.0	.463	.434	.457
	0.4	.482	.426	.381
	0.2	.395	.335	.405

Mean = .419

Range = .101

Sellers

		r_1		
		1.0	0.4	0.2
r_2	1.0	.387	.360	.350
	0.4	.387	.371	.415
	0.2	.402	.502	.364

Mean = .393

Range = .152

Table 3: Bargainers' Profits (as a fraction of first-best gains from trade)
75 Rounds

Buyers

		r_1		
		1.0	0.4	0.2
r_2	1.0	.503	.482	.480
	0.4	.520	.460	.402
	0.2	.406	.326	.433

Mean = .451

Range = .144

Sellers

		r_1		
		1.0	0.4	0.2
r_2	1.0	.371	.382	.366
	0.4	.388	.405	.462
	0.2	.395	.471	.426

Mean = .407

Range = .105

Table 4: Bargainers' Profits (as a fraction of first-best gains from trade)
Last 25 Rounds

We see from these two tables that the mechanism is also fairly robust with respect to the buyer's (seller's) profits, but less so than for the total gains from trade; thus, the range of the entries is a greater fraction of the means in Tables 3 and 4 than in Table 2.

While the results stated above are empirical, theoretical support for the robustness of the sealed-bid mechanism has also been supplied by Linhart, Radner and Schotter (1992). As stated in Section 2, the strategic robustness of a mechanism is a question of the steepness or flatness of the efficiency surface of the mechanism around some salient outcome of the mechanism such as its Nash equilibrium or the truth-revealing outcome. In Linhart, Radner and Schotter (1992) they calculate the efficiency surface of the sealed bid-mechanism. One such surface is presented in Figure 3a below.

Figures 3a and 3b here

What this figure illustrates is the efficiency surface for the sealed bid mechanism when the prior distributions of costs and values are uniform and when agents deviate from truth-telling linear functions by choosing piece-wise linear functions with a slope of 1 until some critical value (cost), V_0 (C_0), and then a slope of zero from that point until the end of the support of the function (assumed in this diagram

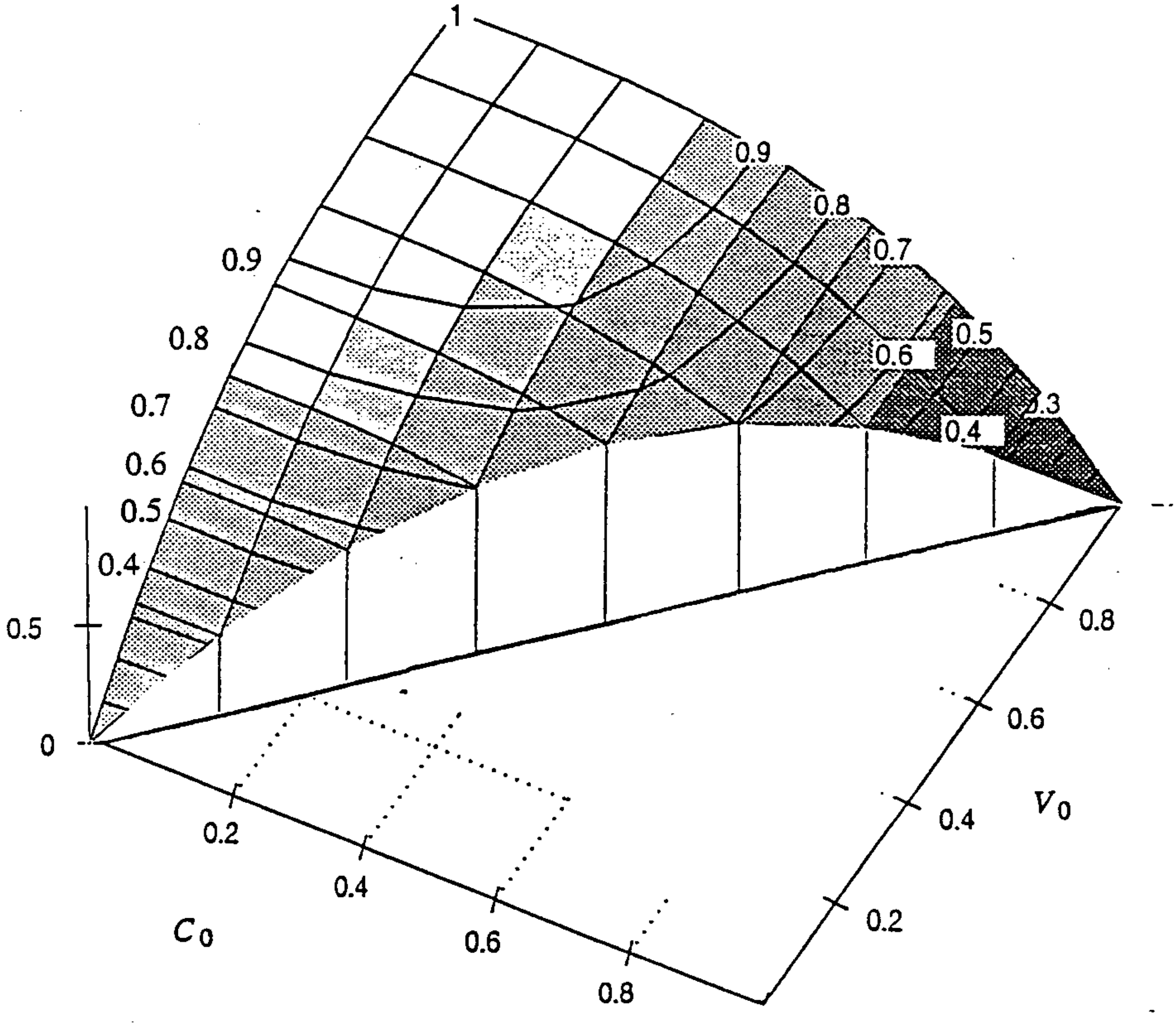

Fig. 3a

Efficiency: Sealed-Bid Mechanism

Broken-Stick Strategies

$r_1 = r_2 = 1.0$

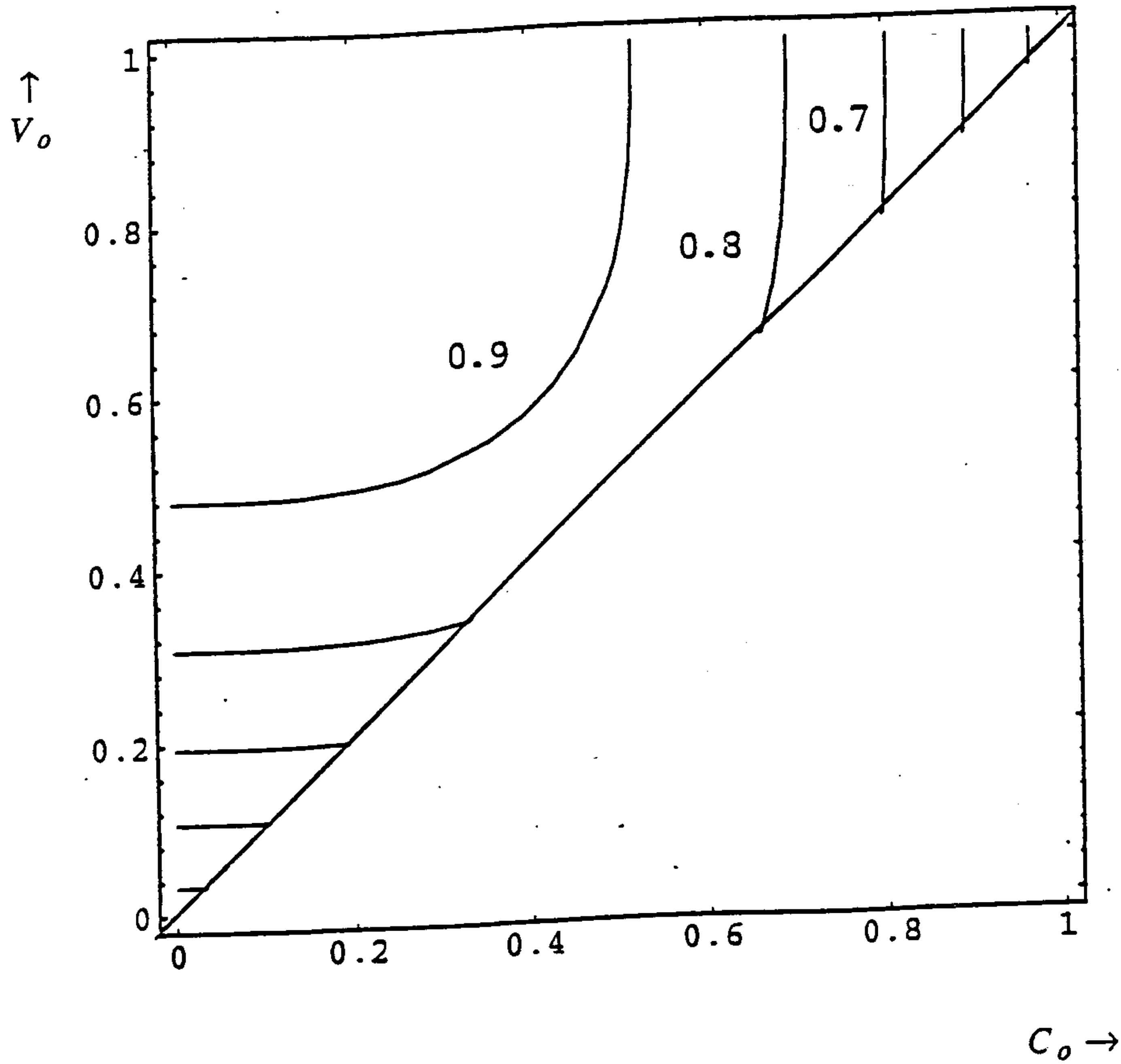

Fig. 3b

Efficiency Contours: Sealed-Bid Mechanism

Broken-Stick Strategies

$r_1 = r_2 = 1.0$

29 B

to be [0, 1]). These deviating strategies are called "broken-stick" strategies since their graphs represent broken sticks with a break at V_0 and C_0.

As we can see, from this diagram and its associated Efficiency Contours in Figure 3b, the efficiency of the sealed bid mechanism is theoretically robust around the truth-telling first-best strategies since for significant deviations of the broken stick type away from this these strategies, the efficiency of the mechanism remains quite high. Similar results are obtained for other prior distributions of types as can be seen in Figures 4 and 5.

The robustness of the sealed-bid mechanism as demonstrated by these diagrams, presents a strong source of support for its use in practical situations. Not only is the sealed-bid mechanism easily understandable, and strategically fair (symmetric) but on efficiency grounds it offers hope for achieving second-best optimal outcomes with a great degree of reliability (it is strategically robust). Other mechanisms will have to be checked on a case by case basis to see if they are as robust as is this mechanism.

3.4: Personality Robustness in An Economic Tournament

One of the areas where mechanisms have been most extensively used is in the field of labor contracting in which the form of the contract between a worker and his or her firm is set. In recent years a move has been made away from individual-based incentive formulae and toward group-based formulae. (See Nalbantian (1987).) Hence, old style piece-rates have yielded way to methods of compensation that rely on variables other than individual performance.

One intensively studied mechanism for compensating individuals at the workplace is a tournament mechanism. In a tournament people are rewarded for their performance relative to the performance of others. In other words, the compensation of a worker is not tied to his or her absolute output as in a piece-rate, but rather to his or her output relative to the output of others (or perhaps some statistic of the performance of all workers in a group). For example, car salesman many times compete for prizes which

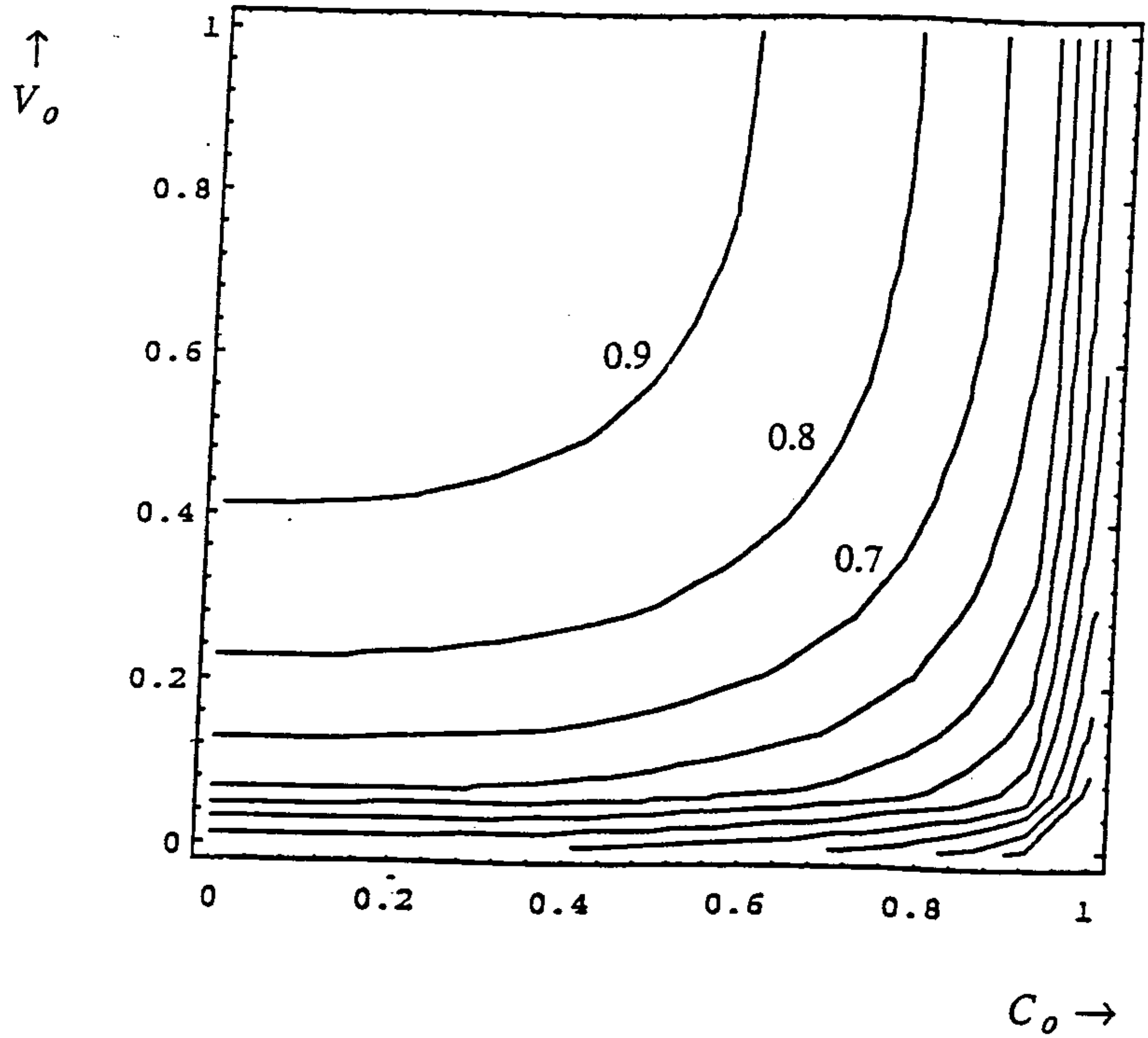

Fig. 4

Efficiency Contours: Sealed-Bid Mechanism

Broken-Stick Strategies

$r_1 = r_2 = 0.4$

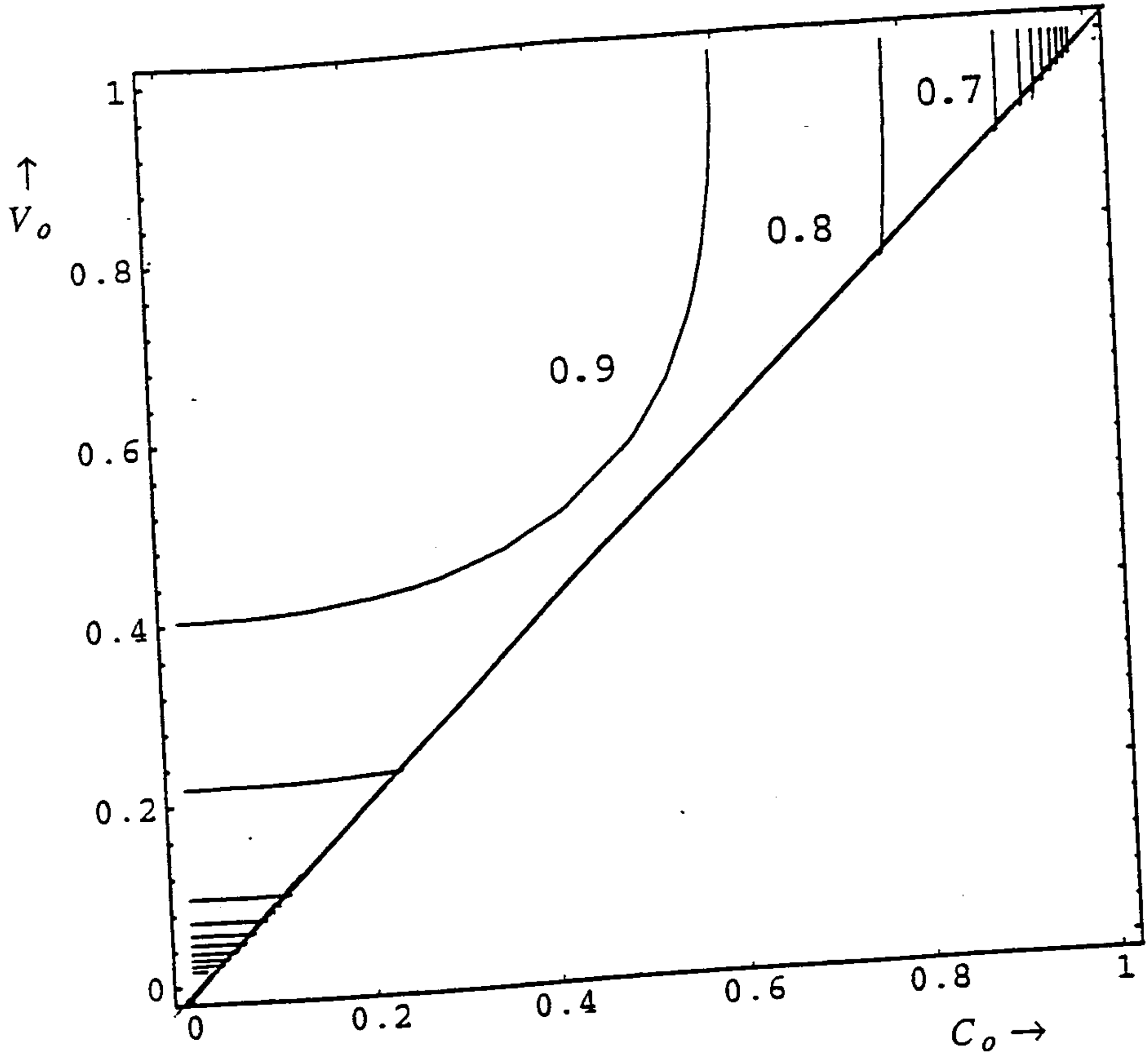

Fig. 5

Efficiency Contours: Sealed-Bid Mechanism
Broken-Stick Strategies
$r_1 = r_2 = 0.2$

are given to that salesman who sells the most cars for a given period of time, Assistant Professors compete for the prize of tenure which is given to that Assistant Professor whose work is judged as being best, and corporate Vice Presidents compete for the big prize in an organization -- the Presidency. In environments where there are both common and idiosyncratic shocks to output, risk averse workers many times will prefer a tournament to a piece rate system since, under a tournament, they are immune to the common shock affecting their output -- such shocks affect all workers equally and hence do not jeopardize their chances of getting the big prize offered by the organization. As a result, if a piece-rate and a tournament both yield equal levels of output from workers, in an environment with common and idiosyncratic shocks, a tournament would seem to be preferable since risk neutral firms would be indifferent between the two while risk averse workers would prefer a tournament. The mechanism selection problem seems easy to solve here since, at least at the theoretical level -- tournaments appear to dominate piece-rates.

At the empirical (experimental) level, things are not so simple. In a series of experiments performed by Bull Schotter and Weigelt (1987) the authors demonstrate that while the behavior of human subjects is consistent with the predictions of tournament theory in the laboratory, in the sense that the mean actions of subjects conforms to the predictions of the theory, there is great variability around these means. Put differently, let us assume that a corporation has many plants or production units located across the United States. In each plant it uses an identical tournament to compensate its workers each predicting the same level of expected output. The results of the Bull, Schotter and Weigelt (1987) experiments indicate that while the mean output of the corporation, averaged over these plants, may in fact equal the expected output predicted by the theory, output will vary greatly from plant to plant. Such variability creates uncertainty at the plant level and risk averse C.E.O.'s or plant mangers may be averse to such risks. For instance, a manager may be branded as a "bad manager" if his plant output is below the average despite the fact that output under a tournament system is proven to be a random variable with a known variable.

If such variability results because different workers react to the rules of the mechanism in different ways and establish different norms of behavior at different plants, such a mechanism would fail the personality robustness criterion described in Section 2. Further, it might be thought that the variability of output might decrease over time as workers learn more about the mechanism. As we will see, such a conjecture has proven not to be the case.

To appreciate some of the specifics here, consider the following simple tournament and the results of the Bull, Schotter, and Weigelt (1987) experiments run to examine its properties.

3.4.1 The Theory of Rank-Order Tournaments

Consider the following two-person, symmetric tournament. Two identical agents i and j have the following utility function that is separable in the payment received and the effort exerted:

$$U_i(p,e) = U_j(p,e) = u(p) - c(e) , \tag{3.4}$$

where p denotes the non-negative payment to the agent and e, a scaler, is the agent's non-negative effort. The positive and increasing functions $u(\cdot)$ and $c(\cdot)$ are, respectively, concave and convex. Agent i provides a level of effort that is not observable and that generates an output y_i according to

$$y_i = f(e_i) + \epsilon_i , \tag{3.5}$$

where the production function $f(\cdot)$ is concave and ϵ_i is a random shock.[6] Agent j has similar technology and simultaneously makes a similar decision. The payment to agent i is $M > 0$ if $y_i > y_j$ and $m > 0$, $m < M$, if $y_i < y_j$.[7] Agent j faces the same payment scheme. Given any pair of effort choices by the agents, agent i's probability of winning M, $\pi(e_i,e_j)$, is just equal to the probability that $(\epsilon_i - \epsilon_j) > f(e_j) - f(e_i)$. Thus i's expected payoff from such a choice is

$$Ez(e_i, e_j) = \pi(e_i, e_j)u(M) + [1 - \pi(e_i, e_j)]u(m) - c(e_i) \ . \tag{3.6}$$

The equations above specify a game with payoffs given by (3.6) and a strategy set E given by the set of all feasible choices of effort. The theory of tournaments restricts itself to pure strategy Nash equilibria to this game. Notice that if the distribution of $(\epsilon_i - \epsilon_j)$ is degenerate either because there are no random shocks to output or because such shocks are perfectly correlated across agents, then the game has no pure strategy Nash equilibrium.[8]

With suitable restrictions on the distribution of the random shocks and the utility functions, a unique, pure strategy Nash equilibrium will exist for the game. This is the behavioral outcome predicted by the theory of tournaments. Testing the theory requires the specification of the utility function, the

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6 O'keefe, Viscusi, and Zeckhauser (1984) point out that the random shock can be interpreted not only as true randomness in the technology but alternatively as random measurement error in the principal's monitoring of output.

7 Some rule is required to deal with cases in which $y_i = y_j$. For simplicity of exposition we ignore this possibility.

8 To see this consider the case in which the random shocks to output are identically zero. At any pair $e_i = e_j$, i can raise his expected utility by raising his effort slightly and so winning the tournament for sure. Thus no symmetric pure strategy Nash equilibrium exists. No asymmetric pure strategy Nash exists either. If such an equilibrium were to exist with $e_i > e_j$, then e_j would have to be zero and e_i infinitesimally higher, but then j would have an incentive to raise e_j, thereby contradicting the existence of the equilibrium.

production function, the distribution of $(\epsilon_i - \epsilon_j)$, and the prizes M and m. One simple specification is the following. For k = i,j,

$$U_k(p_k, e_k) = p_k - \frac{e_k^2}{c} , \tag{3.4'}$$

$$y_k = e_k + \epsilon_k , \tag{3.5'}$$

where $c > 0$ and ϵ_k is distributed uniformly over the interval [-a,a], $a > 0$, and independently across the agents. Effort e_k is restricted to lie in [0, 100]. In this particular case i's expected payoff in the tournament is given by

$$Ez(e_i, e_j) = m + \pi(e_i, e_j)(M - m) - \frac{e_i^2}{c} . \tag{3.6'}$$

Agent j's expected payoff is given by a similar expression. If a pure strategy Nash equilibrium exists in this case, it will be symmetric, $e_i = e_j = e^*$. If the equilibrium is in the interior of [0, 100], each agent's first-order condition must be fulfilled:

$$\frac{\partial Ez_i}{\partial e_i} = \frac{\partial \pi}{\partial e_i}(e^*, e^*)(M - m) - \frac{2e^*}{c} = 0 . \tag{3.7}$$

The concavity of the agent's payoff function ensures that (3.7) is sufficient for a maximum.[9] Given the

9 Naturally, one must also check for corner solutions.

distributional assumptions on the random shocks, this condition can be rewritten as

$$\frac{(M - m)c}{4a} = e . \tag{3.8}$$

Equation (3.8) implies that $0 < (M - m)c < 400a$ is both necessary and sufficient for an interior Nash equilibrium to exist in this example. Notice that (3.8) provides testable implications, namely, that the efforts chosen by agents in the tournaments will increase proportionally with any increase in the spread between the first and second prize, while they will move inversely with both the "width" of the uniform distribution of ϵ and the cost of effort parameterized by $1/c$.

3.4.2 The Bull, Schotter, Weigelt (1987) Experiment

Bull, Schotter and Weigelt tested this simple theory of tournaments (along with a number of variations) with 10 separate experiments. A typical experiment was conducted as follows. They recruited a group of students, usually 24 in number, from economics courses at New York University. They reported to a room that had chairs placed around its perimeter, each chair facing the wall. The students were randomly assigned seats and subject numbers and given written instructions. They informed subjects that another subject was randomly assigned as their "pair member" and that the amount of money they would earn in the experiment was a function of their decisions, their pair member's decisions, and the realizations of a random variable. The physical identity of the pair member was not revealed. The experiment then began. They asked each subject to chose an integer between zero and 100 (inclusive). This was called their "decision number," and each subject entered his or her choice on the work sheet. Corresponding to each decision number was a cost listed in a table in the instructions. With one exception, in all the experiments these costs took the form of e^2/c, $c > 0$, where e represents the decision number and c was a scaling factor used to make sure payoffs were of a reasonable size. After subjects recorded their decision numbers, an experimental administrator circulated with a box containing bingo balls labeled with the integers, including zero, from -a to +a. These were called "random numbers." Each subject would pull a random number from the box, replace it, enter it on his or her work sheet, and then add it to the decision number to yield the "total number" for that round. This information was recorded on a slip of paper, which was then collected from the subject. An administrator compared the total number for each pair of subjects. They then announced which pair member had the highest total number in each pair.[10] The pair members with the highest and lowest total numbers were awarded, respectively, "fixed payments" M and m, M > m. Each subject then calculated his or her payoff for the round by subtracting the cost of his or her decision number from the fixed payment. All the tournament's parameters, except the identity of each subject's pair member, were common knowledge.

When this round was completed and the payoffs were recorded, the next round began. All the rounds were identical. Each group of subjects repeated this procedure for 12 rounds. When the last round was completed, the subjects calculated their payoff for the entire experiment by adding up their payoffs for the 12 rounds and subtracting $2.00. The experiments lasted approximately 75 minutes, and subjects earned between $5.00 and $13.00.[11] These incentives seemed to be more than adequate.[12]

The experiment replicated the simple example of a tournament given in the previous section. The

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10 In one experiment the size of the difference between the total numbers of the pair members was also announced while in another experiment the decision numbers were also announced. If both members of a pair had the same total number, then a coin was tossed to decide which pair member was to be designated as having the highest total number. The subjects were informed of this tie-breaking procedure before the experiment began.

11 One experiment was run for 25 rounds, and in this one $10 was subtracted from the sum of the payoffs for each round. This experiment lasted for almost 2 hours.

12 To check that these incentives were adequate, experiment 1 was also run with payoffs quadrupled so that subjects could, and did, win over $40. The results of this experiment did not differ substantially from that described in the text.

decision number corresponds to effort, the random number to the random shock to productivity, the total number to output, and the decision cost to the disutility of effort. A comparable piece-rate experiment was also run.

3.4.3 Experimental Results

The broad outlines of the results of the experiments are given in Table 5 and figures 6, 7 and 8. Table 5 shows summary statistics for the first and last six rounds as well as the twelfth round. For the two six-round periods it reports, for each experiment, the six-round means and variances of the average (across pairs) choices made.[13] It also displays the average choice and variance for the last round. Figures 6, 7 and 8 plot for each experiment the average choices made in each round.

The piece rate experiment serves as a point of comparison for many of the tournament experiments and so merits our attention first. As can be seen from Figure 6 and Table 5, the piece rate system tested did very well. The theoretical mean effort level was 37 (just as in our baseline tournament), and the mean effort level in the twelfth round was 37.38. This mean is not significantly different from 37 at the 95 percent confidence level using a median test. The variance across subjects was 33.66. This variance is remarkably small when compared with the tournament variances. From observation of Figures 7 8, and 9 it appears as if tournaments also perform remarkably well in terms of determining behavior which is, on average, consistent with the predictions of the theory. In all of these figures we see a convergence over time of the mean effort level of subjects toward the predictions of the theory. This is true for experiments where the mean is 37 as well as other tournaments where the parameters were changed so that the mean increased to 74. It was true for experiments where

Table 5: Experimental Results: Means and Variances

13 Recall that the variance refers to the variance of the average choice of effort within a tournament, across tournaments.

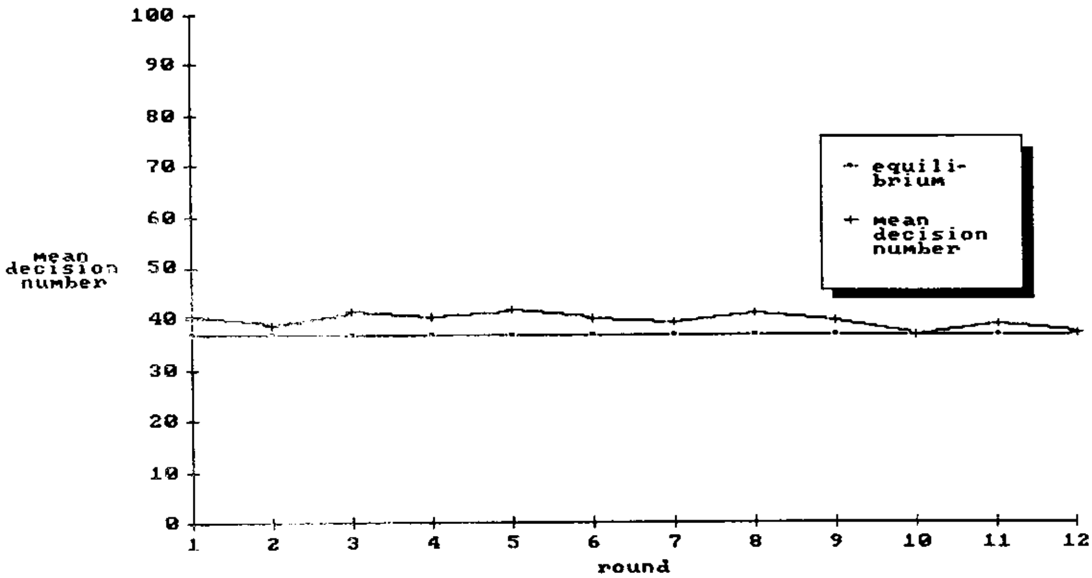

FIG. 6 —Piece rate experiment

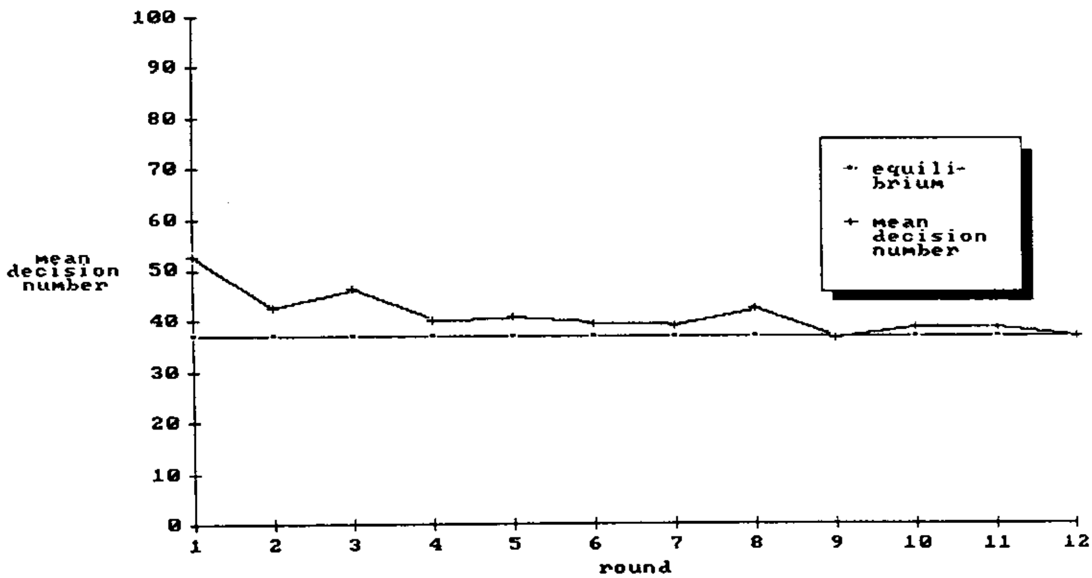

FIG. 7 —Baseline experiment (37)

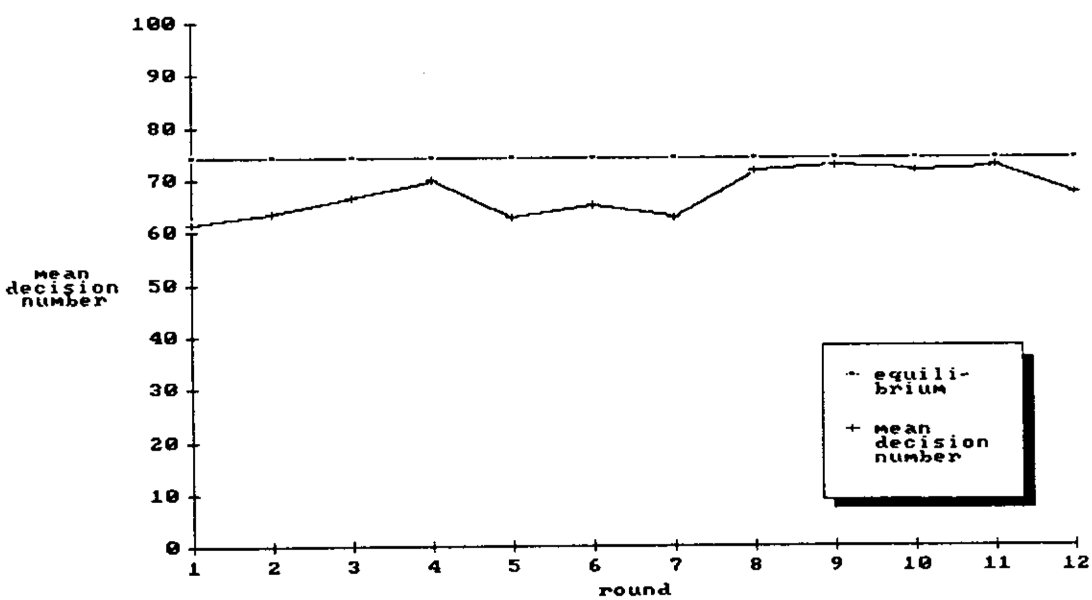

FIG. 8 —Equilibrium 74 experiment

37A

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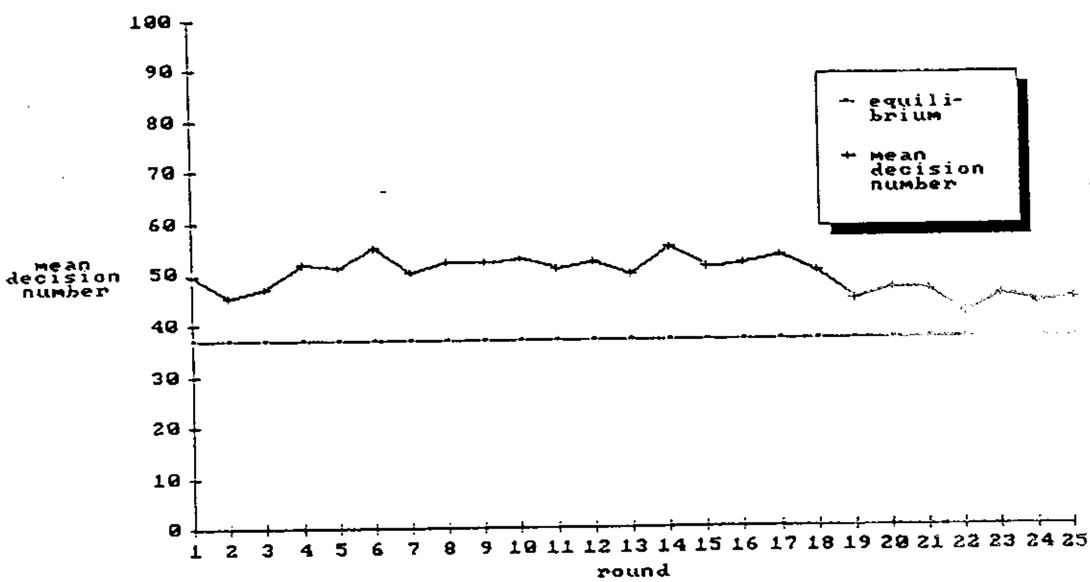

FIG. 9.—25-round experiment (37)

37B

	Mean Decision Number		Mean Variance in Decision Numbers		Mean Decision Number	Variance in Decision Numbers
Experiment	Rounds 1-6	Rounds 7-12	Rounds 1-6	Rounds 7-12	Round 12	Round 12
Baseline 37	43.62	38.75	508.32	499.67	36.94	577.28
Equilibrium 74	64.92	69.91	867.17	892.05	67.61	1005.37
Piece Rate	40.44	38.91	103.61	87.38	37.38	33.66
	Rds 1-12	Rds 13-25	Rds 1-12	Rds 13-25	Round 25	Round 25
25 Round Equilibrium 37	50.62	48.00	303.88	362.01	44.63	466.44

the tournament was repeated 12 times and well as when it was repeated 25 times. What is remarkable, however, is that as can be seen in Table 5, despite the convergence of these means, there is a persistence of the variance even in the experiment lasting 25 rounds (where the variance was 466.44 in round 25 as opposed to a variance of 33.66 in the twelfth round of the piece-rate experiment.

In summary, while tournaments appear to be efficient compensation mechanisms, they do appear to perform quite badly when judged by our personality robustness criterion. Whether this drawback is enough to counter their other benefits is a question left to real world decision makers. However, I certainly think that this factor should be considered when a mechanism selection problem is present.

Section 4: Conclusions

This paper has dealt with the problem of mechanism selection. It has tried to emphasize the point that the criteria which economists use to evaluate the aesthetics of the mechanisms they design may not be the same criteria used by real world decision makers when they have to actually decide on which mechanism is the correct one for them to use in their organization. In the pages above we have outlined 7 such criteria and have presented a number of experimental studies where mechanisms that have either been designed by economic theorists or used in industry have been evaluated by these criteria. It is my hope that a better understanding of the **mechanism selection** problem will lead to the design of more practical mechanisms and their wider adoption in the corporate and governmental world.

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