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BIDDING AND AUCTIONING INSTITUTIONS: EXPERIMENTAL RESULTS

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SOCIAL SCIENCE WORKING PAPER 71

December 1974

BIDDING AND AUCTIONING INSTITUTIONS: EXPERIMENTAL RESULTS

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Among the laboratory experimental studies of market price behavior there are numerous experiments designed on the basis of various bidding and auctioning processes of allocation. The theme of this conference will serve as the organizing principle of this paper which presents a summary of several published and previously unpublished experiments in auction and sealed-bid market behavior.

I. VALUES, INSTITUTIONS AND MARKET STRUCTURE AS TREATMENT VARIABLES

In discussing the use of experimental methods to determine the equilibrium and dynamic properties of market price behavior it is helpful to distinguish three classes of experimental market "treatment" variables:

A. Individual values and their aggregation to form market values. In isolated single-commodity market experiments such values are defined as the individual supply and demand schedules, or simply the aggregate supply and demand conditions that bound price-quantity behavior.

B. The institution of contract. This is defined as the entire set of rules and procedures of an experiment which taken together

specify the process whereby individual subjects communicate, exchange information, and form binding contracts.

C. Market structure. This is defined by the number of participants (buyers and sellers) and their relative "power" in the sense of relative demand or supply (cost) capacity.

A complete set of market experiments can be viewed as providing observations on the mapping from values (supply and demand), institutions and market structure into price-quantity outcomes (price levels, price trajectories, quantities exchanged). That is, price-quantity outcome = f (values, institutions, market structure). None of the experiments to be summarized in this report have systematically varied market structure except insofar as changes in the conditions of supply and demand have been effected by changing the number of sellers and buyers. But in each case reported here numbers are large enough and economic power sufficiently dispersed to yield competitive price behavior. However, empirically, "large" in this context typically means only about three or more sellers (and as many buyers)

There are a number of laboratory studies (Hoggatt, 1959; Fouraker and Siegel, 1963; Friedman, 1963; Murphy, 1966) of duopoly and triopoly bargaining in which buyer response is simulated by the experimenter using a pre-specified demand function. This literature will not be treated here since it is only tangentially related to bidding and auctioning, and has been very ably summarized by Friedman (1969).

The institutions of contract that have been studied experimentally, and that will be summarized below, are defined as follows:

(1) Double auctions.

(i) In this market in each trading period of specified duration, any buyer is free at any time to make an oral bid to buy one

unit of a homogeneous commodity. Any seller is free at any time to make an oral offer to sell one unit. Any buyer is free to accept the offer of any seller and any seller to accept the bid of any buyer. An accepted bid or offer constitutes a binding contract. A given bid or offer is outstanding until it is either accepted or another bid or offer is made. The new bid or offer does not have to provide better terms than a previous bid or offer. Hence, no "convergence rules" are imposed on bid and offer sequences, and only one (the last) bid or offer is outstanding at a time. Over-the-counter security markets and real estate markets have the feature that a bid or offer not accepted is not binding at a later time unless it is restated.

(ii) A variation on the above institution is to write all bids and offers on a blackboard, visible to all. Following an initial unrestricted bid or offer, any new bid (offer) is admissible only if it is higher (lower) than the last bid (offer) until a contract occurs. When a contract occurs a new "auction" begins with an initial unrestricted bid or offer, and so on. The requirement that a new bid or offer provide better terms than the last is characteristic of organized trading as on the New York Stock Exchange (Leffler and Farwell, 1963, p. 187, 191).

(2) Bid Auction. Buyers are free to make bids and sellers to accept bids as in the double auction, but sellers are not permitted to make offers. This procedure is typical of art auctions and auctions for the sale of farm animals and machinery.

(3) Offer Auctions. Sellers make offers and buyers may accept offers, but buyers cannot make bids. As an experimental treatment variable this institution is the negative of the bid auction.

(4) Posted Pricing. Under this institution each seller (buyer) independently selects a "take-it-or-leave-it" price offer (bid), i.e. a price is selected without knowledge of the prices being selected by competitors. These prices are then posted on a blackboard where they are visible to all buyers and sellers. Next a buyer (seller), chosen at random, selects a seller (buyer), and makes that seller (buyer) a quantity offer at his posted price. The seller (buyer) then responds with a quantity (any portion of the offer) acceptance which forms a binding contract. If some portion of the quantity offer is not accepted, the buyer (seller) may choose a second seller (buyer) and make a quantity offer, and so on. When the first buyer (seller) has finished his contracts, a second, chosen at random, selects a seller (buyer), makes a quantity offer, and so on, until all buyers (sellers) have completed their contracts.

Most retail markets have the feature that sellers post prices which are not subject to alteration for some considerable period of time. Clothing merchants post selling prices for spring garments, Sears Roebuck publishes spring-summer and fall-winter catalogues of selling prices, and refiners post price bids at which they are willing to buy crude oil. In the experimental procedure, the fact that a given seller may not satisfy the demand of a buyer corresponds to a stock-out in retail markets. That is, retailers post a price, and normally do not specify a quantity (except perhaps to say "while they last"), but stocks may be exhausted before all buyers are satisfied.

(5) Discriminative Sealed-bid Auction. In this institution in each trading period the seller offers a specified quantity, Q, of a homogeneous commodity and invites buyers to tender bids independently at stated prices for stated quantities of the good. The bids are arrayed from highest to lowest, and the first Q bid units are accepted with a random device used for allocating among tie bids at the lowest accepted price. All accepted bids are then filled at their full bid prices. This procedure has been characteristic of the auctioning of U.S. Treasury bills.

(6) Competitive Sealed-bid Auction. The rules are the same as in (5) except that all accepted bids are filled at the price of the lowest accepted bid. This is approximately the procedure followed in the French auctioning of new stock issues (see McDonald and Jacquillat, 1974).

As an experimental treatment variable the institution of contract is specified and controlled in any given experiment through the design of subject instructions. To write the instructions for an experimental task is to define a trading institution in all its mechanical detail. For examples of instructions defining some of the above exchange institutions refer to Smith (1964, pp. 199-201; 1967, pp. 76-78), and Williams (1973, pp. 111-113).

II. INDUCING CONTROLLED SUPPLY AND DEMAND CONDITIONS

If (i) for every experimental subject more currency is better, i.e. if U(M) is a subject's unknown utility of money, with $U'(M) > 0$ for all $M \geq 0$, and (ii) the experimental task required to earn M is simple enough so that the subjective transactions cost (i.e. the disutility of learning, computing, and executing the experimental

procedures) is negligible, then actual monetary rewards can be used to induce value in the form of any predesigned demand or supply function on each subject. Aggregate market demand or supply will then be the quantity summation of these individual demand or supply functions.

This is accomplished rather simply. The instructions inform a subject, say a buyer, that at the end of each of a series of trading periods the person will receive a sum of money $R(q) - \sum_{k=1}^{q} p_k$, for units purchased at prices $p_1, p_2, \ldots, p_q$. $R(q)$ is increasing and concave in q, the number of units of an abstract commodity purchased during the period. The classical definition of demand is the number of units that will be purchased as a function of a hypothetical fixed price p. Hence subject hypothetical utility is $U[R(q) - pq]$, and for a maximum $U' \cdot (R' - p) = 0$, or $q = R'^{(-1)}(p)$, if $U' > 0$, where $R'^{(-1)}(p)$ is the induced individual demand valuation per trading period independent of the individual U function. The sum over all such buyer valuations defines the experimental market demand schedule (as illustrated on the left of Charts 1 - 7). A subject seller is instructed that he will be paid $\sum_{k=1}^{q} p_k - C(q)$, for selling q units at prices $p_1, p_2, \ldots, p_q$, where $C(q)$ is increasing and convex in q. For a maximum of $U[pq - C(q)]$, $U' \cdot (p - C') = 0$, or $q = C'^{(-1)}(p)$, if $U' > 0$, where $C'^{(-1)}(p)$ is the induced individual supply valuation. Summing over such individual supply valuations yields the experimental market supply (see Charts 1 - 7).

By imposing the appropriate reward structure in this way it is possible to effect virtually complete control over the experimental conditions of supply and demand to study the effect of any given configuration on price adjustment behavior. The experimenter always has complete knowledge of the conditions of supply and demand that generated a given sequence of observations. How much knowledge the subjects have is an experimental treatment variable. In the experiment reported here subjects only have knowledge of their own

supply or demand functions. A subject is therefore never in a position of having more knowledge of market conditions than any nonlaboratory economic agent.

For experimental markets in which the supply and demand schedules are not too asymmetric (i.e. total producer surplus is not greatly different from consumer surplus) and which are conducted over periods of less than 40-50 minutes, satisfactory results can often be obtained without actual monetary rewards. But motivation is likely to be weak when subjects bargain for "points" so that results are more likely to be effected by boredom and the cost of transacting once the task becomes routine.

Of the twenty experiments summarized here only the five whose results are exhibited in Charts 1-5 were conducted without actual cash profit rewards.

III. DOUBLE AUCTIONS

The motivation for selecting the double auction for extensive experimental study (Smith, 1962) was based on the conjecture that this institution was the one under which classical supply and demand theory had the best chance of being validated. However, I did not seriously expect competitive price theory to be supported by these initial probes; such was the power and influence of the Chamberlin-Robinson revolt against competition. But if competitive theory had validity under the double auction, this would provide the "control case" or reference institution against which other forms of market organization could be compared.

The salient features of the double auction experiments can be listed as follows:

1. No subject is given any information on the cost or revenue schedules provided to the other subjects or on the number of buyers or sellers,

or on the level at which contract prices might occur. A subject only has information on his own cost or revenue conditions, the bids or offers being made, and the prices at which contracts are executed.

2. Any buyer (seller) can make an oral price bid (offer) for one unit at a time. Any seller (buyer) can accept the bid (offer) of any buyer (seller).

3(i) A bid (offer) is outstanding only until it is either accepted or a new bid or offer is made, whether or not the new bid or offer provides better terms than the last. Consequently there is only one quotation (a bid or an offer) outstanding at any one time.

3(ii) A bid (offer) is outstanding until it is either accepted or a new bid (offer) is made. A new bid (offer) is admissible only if it provides better terms, i.e. is higher (lower) than the previous bid (offer). Once a first bid and a first offer have been made, thereafter two quotations (one bid and one offer) will be outstanding at any one time. When a contract is executed a new "auction" begins with a new bid or offer which need not provide better terms than the last.

4. The market is conducted over a sequence of several market periods with constant controlled conditions of supply and demand from period to period.

5. No subject participated in more than one experiment in order to control on previous trader knowledge and experience. This specification provides minimum conditions of knowledge and experience.

The contract price sequences for twelve double auction experiments are shown in Charts 1-7. In each chart the controlled experimental market supply and demand are shown on the left. The presentation and discussion of these results will be organized to illustrate five empirical propositions.

Proposition 1. Contract prices converge to "near" the theoretical (Supply = Demand) equilibrium level usually within the first twenty to thirty transactions. The more slowly converging markets are associated with very asymmetric supply and demand (producer surplus is substantially different from consumer surplus).

The concept of prices being "near" the competitive equilibrium eludes satisfactory, precise, objective definition. The requirement that, beyond some transaction or period, every contract be at the competitive equilibrium price is precise but clearly too strong although such results are obtainable as in the second experiment in Chart 7. All econometric studies of individual markets allow for noise in the competitive price hypothesis. A requirement that contract prices differ from the monopoly and monopsony levels by statistically significant amounts, is precise but much too weak as is evident in the contract price sequences in Charts 1-7. There are few if any trading periods in these sequences for which the monopsony and monopoly price hypotheses would fail to be rejected at high levels of significance. Such tests might be impressive but not very relevant. What is missing in competitive price theory are adequate price adjustment models that permit more definitive statements about the characteristics of equilibrium. The assertion that all of the double auction experiments reported in Charts 1-7 converge to "near" the competitive equilibrium is neither very objective nor precise, but I have found in oral presentations that

virtually all observers agree subjectively that convergence is "good" or "remarkable," in these experiments.

The experiment in Chart 1 illustrates a case in which contract prices tend to equilibrium in the sense that every contract price is within the range $1.75 to $2.25 between the first intramarginal seller and buyer valuations. The contracts in Chart 2 are relatively more erratic than in Chart 1, but by trading period 3 have converged very closely to the equilibrium price. The two experiments in Charts 3 and 4 illustrate the effect of doubling the supply and the demand of each trader. In Chart 3 each subject could buy (or sell) one unit per trading period, while in Chart 4 two units could be bought (or sold) in each trading period. Consequently, in Chart 4, there is roughly as much convergence in one trading period as there is in two trading periods of Chart 3. This suggests that convergence is related to transaction experience, not just to "trading period" experience. Similarly, in Chart 5 each buyer and seller had multiunit revenue and cost schedules, and the larger volume of transactions produced substantial convergence by the end of the first trading period.[1]

The three experiments in Chart 7 provide the most rigorous test of the equilibrating power of the double auction.[2] In these experiments all rent, or pure profit, is allocated to buyers at the competitive equilibrium price. The eleven buyers each receive $1.10 in trading profit per period plus a 5 cent commission, while eleven of the sixteen successful sellers receive only the 5 cent commission. In all three replications sellers resist the tendency for prices to decline to seller unit cost, but by period 4 most contracts are very near the equilibrium, $3.10.

Proposition 2. Quantities exchanged per period rarely differ from the theoretical (S = D) equilibrium by more than a single unit in any trading period.

This proposition is supported in every trading period for all the experiments in Charts 1-4, 6, 7. The exception is the multiunit case in Chart 5 in which there were no cash rewards, and the experimental task was made more difficult by giving the subjects multiunit revenue and cost schedules rather than single unit costs and resale prices as in the other experiments. However, other multiunit experiments using cash rewards (Plott and Smith, 1975) and the bid auction institution did not yield a deficient volume of transactions. This suggests that the proposition holds very broadly when motivation is based on cash rewards.

The fact that the quantities exchanged are very close to the theoretical quantity even in the initial period when there is the least amount of information is especially significant. An examination of individual trades reveals that even in the first trading period it is common for submarginal buyers and sellers to be unable to make contracts (cf. Smith, 1962, Table 1, p. 117). Auction markets are therefore quite efficient in excluding submarginal units even before contract prices have converged to their final levels. Consequently the more erratic price variations observed initially have a much greater effect on income distribution than upon allocative efficiency (Plott and Smith, 1975).

Proposition 3. A variation on the double auction rules in which a bid (offer) is not admissible unless it provides better terms than the previous bid (offer) does not appear to provide any significant increase in the convergence rate of contract prices.

This proposition arose from an attempt to test the hypothesis that convergence would be more rapid when the auction rules required a bid or an offer to provide improved terms. Four experiments with identical and symmetrical market supply and demand schedules (Chart 6) were conducted each with a different set of subjects.[3] Two of the experiments, designated 1(i) and 2(i) used the double auction variation (i) above, while two of the experiments designated 1(ii) and 2(ii) used variation (ii) requiring bids and offers to improve. From the contract price sequences alone it is not evident that differences due to the treatment variable (compare the charts vertically) are any greater than differences due to sampling (subject) variation (compare the charts horizontally).

Table 1 compares the variance of contract prices period by period pooled across the two experimental sessions, under the two treatment conditions. In periods 2 through 4 the variance is significantly greater ($\alpha < .10$) under rule (i) than rule (ii), but in periods 1 and 5 the variance ratio is less than unity. These comparisons do not inspire confidence in the hypothesis that rules requiring bids and offers to improve will speed convergence in the sense of reducing period-by-period variance. The hypothesis may be true but the effect too small to be established without a large number of experimental replications.

Proposition 4. The sampling variation (among different subject groups) in market price adjustment paths is considerable, but the variation in equilibrium prices (contract prices in the final period of trading) is minor.

The four experiments in Chart 6 tend to support this proposition. All four experiments yield contracts very near the $2.10 equilibrium in periods 4 and 5, yet 1(ii) converges from above, 2(i) converges generally from below, while 1(i) and 2(ii) exhibit greater price variation than the other two experiments. Chart 7 exhibits the results of three double auction experiments using identical supply and demand but

TABLE 1

Trading Period	σ^2_{ii}	σ^2_i	$F = \sigma^2_{ii}/\sigma^2_i$
1	.06344	.10580	0.60
2	.04023	.01542	2.61
3	.01766	.00266	6.65
4	.00506	.00246	2.06
5	.00133	.00138	1.00

different subject groups. The variation in the contract price sequences is entirely attributable to differences among the three subject samples of size 27 each. Thus in the second experiment only one first-period contract is below $3.50, whereas in the third experiment only one is above $3.50. The price paths are markedly different, but fourth period contracts are all very near the $3.10 equilibrium.

Proposition 5. Contract price convergence is more likely to be from below (above) when producer's surplus is greater (less) than consumer's surplus.

Clearly, in Chart 7, such experimental markets must converge from above if sellers are to sell at a positive profit. Less extreme cases, such as in Charts 3 and 4, should rarely if ever converge from above. Chart 6 supports proposition 5 by illustrating the greater variability in convergence mode (from above, below, or random around the equilibrium) when producer's and consumer's surplus are equal.

The empirical evidence summarized in Charts 1-7 provides very strong support for static competitive price theory when markets are organized on the principle of the double auction. It is also clear that the information requirements for the achievement of competitive equilibrium prices are very weak. The argument of Knight, Stigler and Chamberlin (see Shubik, 1959, pp. 169-171) and of many textbook authors, that "perfect information and price "taking" behavior are required for establishing competitive prices, is not supported by the experimental evidence. On the other hand Marshall's (1949, p. 333-334) famous description of market price determination in a hypothetical corn market is not contradicted by this evidence. The position of Hayek (1945) that an

important feature of decentralized pricing is that it economizes on information, is also consistent with the results of these double auction experiments. Marshall (p. 334) also notes perceptively that it is not necessary for the competitive price argument "that any dealers should have a thorough knowledge of the circumstances of the market." There are no experimental results more important or more significant than that the information specifications of traditional competitive price theory are grossly overstated. The experimental facts are that no double auction trader needs to know anything about the valuation conditions of other traders, or have any understanding or knowledge of market supply and demand conditions, or have any trading experience (although experience may speed convergence), or satisfy the quaint and irrelevant requirement of being a price "taker" (every trader is a price maker in the double auction).

IV. COMPARISON OF BID, DOUBLE AND OFFER AUCTIONS

One-sided oral auctions lead to contracts tending to favor the silent side. If only buyers quote prices (the bid auction), the bids tend to begin much below the competitive equilibrium but thereafter to rise because not all such bids are accepted (there is excess demand). As buyers raise bids competitively to induce sales, sellers learn that it is to their advantage to wait, i.e. the more silent role of sellers is an aid to tacit collusion. Contract prices tend to rise above the competitive equilibrium, but the rise is limited by the fact that the resulting excess supply causes some queuing on the part of sellers to accept bids. This queuing is expressed in the form of ties by two or more sellers to accept a bid. The process is reversed when sellers make offers.

Proposition 6. Let $F_B^t(P)$, $F_D^t(P)$, and $F_O^t(P)$ be the number (or percentage) of contract prices executed at P or greater in trading period $t > 1$ under the bid, double, and offer auctions respectively. Then

$$F_B^t(P) \geq F_D^t(P) \geq F_O^t(P), \quad t > 1.$$

That is, prices in the bid auction stochastically dominate prices in the double auction which stochastically dominate prices in the offer auction. Hence, contracts tend to be executed to the disadvantage of the side having the price initiative.

Chart 8 illustrates the empirical distribution of contract prices in successive trading periods for six experiments consisting of two replications under each of these three treatment institutions (see Smith, 1964). The two "control" experiments using the double auction rules are those labeled 1(i) and 2(i) in Chart 6. The supply and demand designs are the same as those appearing on the left of Chart 6. The dominance relation stated in proposition 6 is supported by these data and is statistically significant (Smith, 1964, pp. 189-192). These results suggest that both the dynamic and equilibrium properties of exchange prices may be affected by the institutional rules or practices governing price initiative (Plott and Smith, 1975).

V. POSTED-BID VERSUS POSTED-OFFER INSTITUTIONS

The first experimental investigation of posted pricing and the determination of its effect on competitive equilibrium is due to Williams (1973). Empirically he establishes that when buyers post bids, contract prices are lower than when sellers post offers. This is the reverse of the result from comparing the oral bid and offer auctions; posted pricing operates to the advantage of the price initiator. The process of posting a "take-it-or-leave-it" price

(for all units to be offered) tends to support collusive coordination among independent traders. The fact that only inter-period price adjustments are possible, retards and perhaps prevents equilibrium convergence.

Proposition 7. Let $G_B^t(P)$ and $G_O^t(P)$ be the number (or percentage) of contract prices executed at P or greater in trading period $t > 1$ under the posted-bid and posted-offer institutions respectively. Then

$$G_B^t(P) \geq G_O^t(P), \quad t > 1.$$

That is, prices in the posted-bid institution stochastically dominate prices in the posted-offer institution.

The empirical bid distributions $G_B^t(P)$ and $G_O^t(P)$ are shown in Chart 9 for six trading periods of four experimental sessions reported by Williams (1973, p. 102). The data from two sessions using posted bids are combined period-by-period to generate the distribution $G_B^t(P)$. Two sessions using posted offers are combined to generate $G_O^t(P)$. The dominance relation of proposition 7 is supported by these data, and is statistically significant (Williams, 1973, p. 104-105). The results of the posted-bid sessions of Williams have been replicated (Plott and Smith, 1975) using a different subject pool and modified instructions. Williams' results appear to be very robust.

VI. SEALED-BID AUCTIONS

Six sealed-bid auction experiments have been reported by Smith (1967). Belovicz (1967) has considerably extended this work in a study consisting of twenty-seven sealed-bid auctions conducted under a variety of different conditions. The experimental paradigm is one in which subjects submit sealed bids for eighteen units of a commodity that can be resold at a price determined by a rectangular distribution over the nine prices $1.15 to $1.95 (Chart 10). The purchase cost is determined as described in either paragraphs (5) or (6) of section I.

Using the discriminitive rules subjects tend to submit lower bids than when the competitive rules are used. This is because the accepted bids are filled at the full bid price. Under the competitive rules an accepted bid is filled at the lowest accepted bid price, and profit is independent of the bid price submitted. Consequently, there is an incentive to bid higher to assure acceptance with no penalty in the form of higher purchase cost when the bid is above the lowest accepted bid.

Proposition 8. Let $H_C^t(B)$ and $H_D^t(B)$ be the number of bids accepted at B or greater in trading period $t > 0$ in the competitive and discriminative sealed-bid auctions, respectively. Then

$$H_C^t(B) \geq H_D^t(B), \quad t > 0.$$

That is, accepted bids in the competitive sealed-bid auction stochastically dominate bids in the discriminative sealed-bid auction.

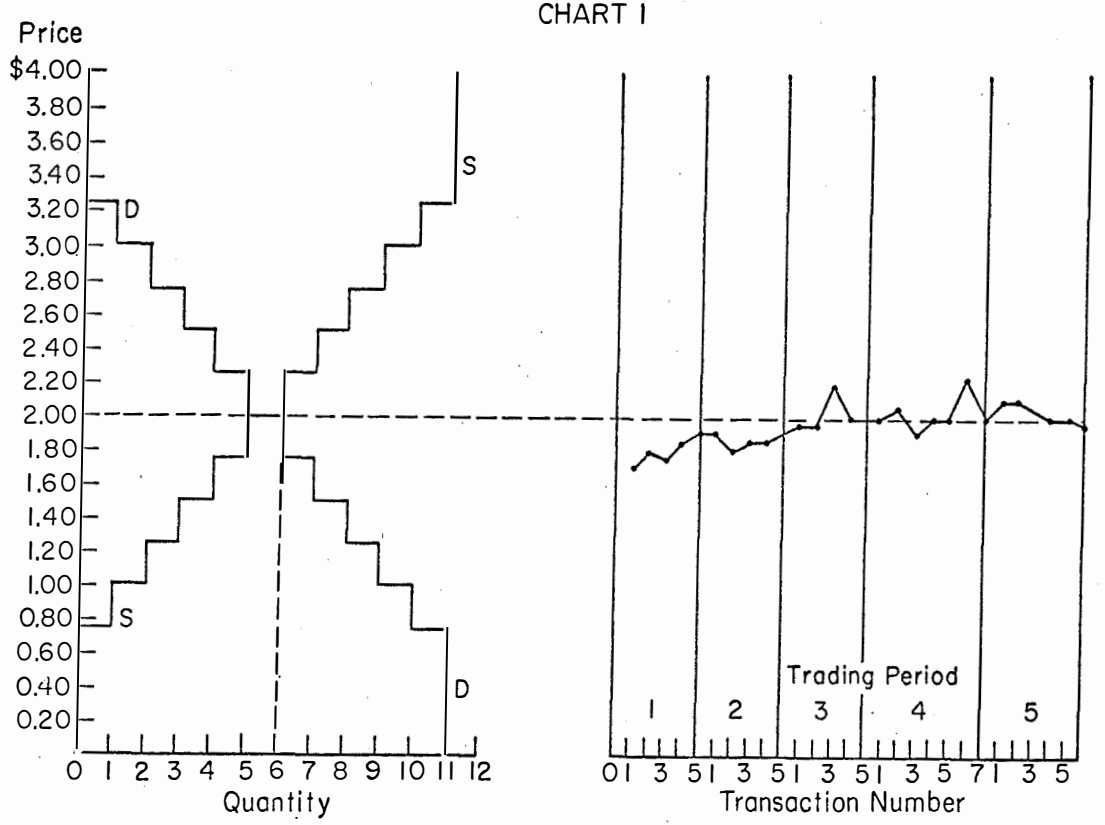
Chart 10 compares the bid distributions $H_C^t(B)$ and $H_D^t(B)$ for three different sets of paired competitive-discriminative experiments. In the top pair, each of thirteen subjects in each experiment submitted up to two bids each per trading period providing eight rejected bids.

In the middle pair there were twelve rejected bids (fifteen subjects), and in the last pair there were sixteen rejected bids (seventeen subjects). The dominance relation of proposition 8 is supported in all three comparisons. Belovicz (1967) in a much more comprehensive study establishes that this block of experimental results can be independently replicated.

VII. CONCLUSION

The potential of experimental analysis for the study of bidding and auctioning processes has very wide but as yet undefined bounds. I am not aware of any exchange process that could not be studied experimentally in some simplified form. The value of such studies cannot be fully assessed at this time. Perhaps the most important ultimate value is to provide a rigorous testing of our ability to model elementary behavior before confronting such models with field data. This is partly illustrated in the study of the French sealed-bid auction (McDonald and Jacquillat, 1974) in which the authors build upon the results of competitive sealed-bid auction experiments to test the efficiency of the French marketing of new stock issues. Another possibility is to provide empirical justification and preliminary experience for the design of field experiments. This is especially well illustrated in some of the bond marketing experiments by the U.S. Treasury reported at this conference. Some of these field policy experiments seek to assess the effect of competitive auction rules and were undertaken with knowledge of the laboratory experimental results on competitive versus discriminative auctions. Finally, experimental methodology has potential in exploring the policy implications of new institutions, or alterations in existing institutional rules. Experimental studies of exchange institutions has the potential of increasing our understanding of decentralized allocation processes with implications for antitrust policy and the use of decentralized institutional forms of market regulation and constraint.

CHART I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1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
D
S
S
D
0 1 2 3 4 5 6 7 8 9 10 11 12
Quantity
Trading Period
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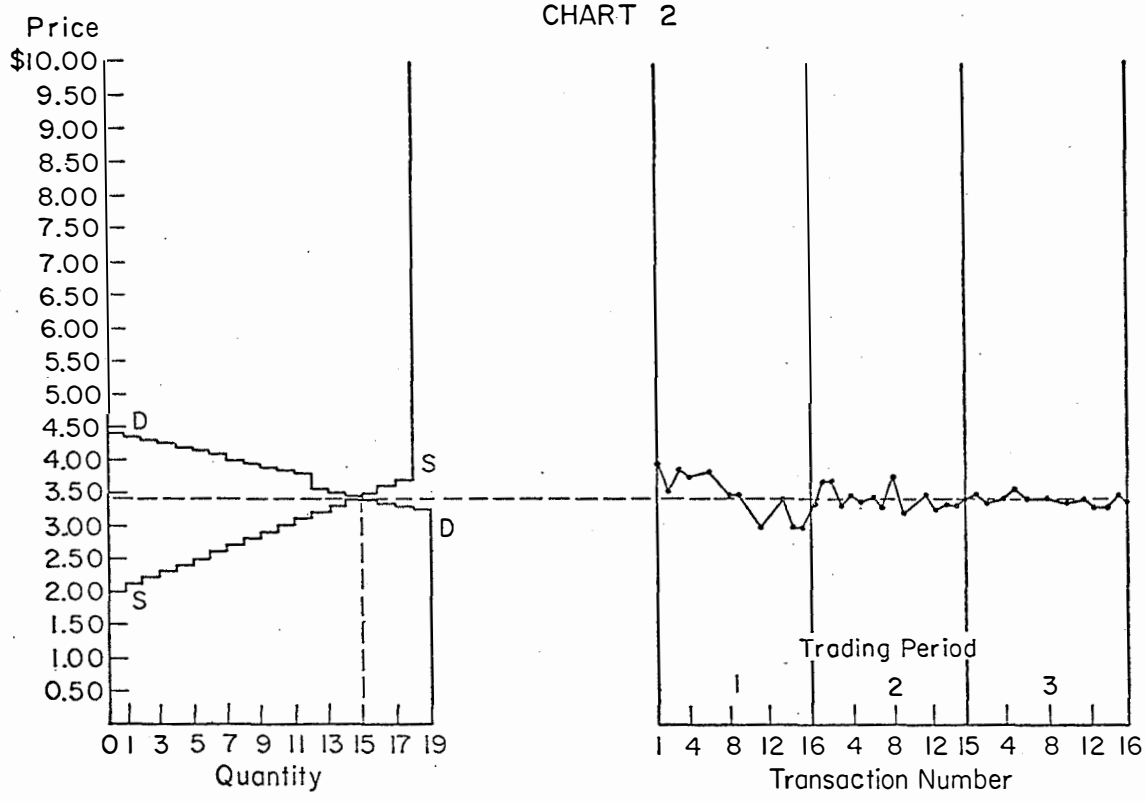
2
3
4
5
01 3 51 3 51 3 51 3 5 71 3 5
Transaction Number

CHART 2



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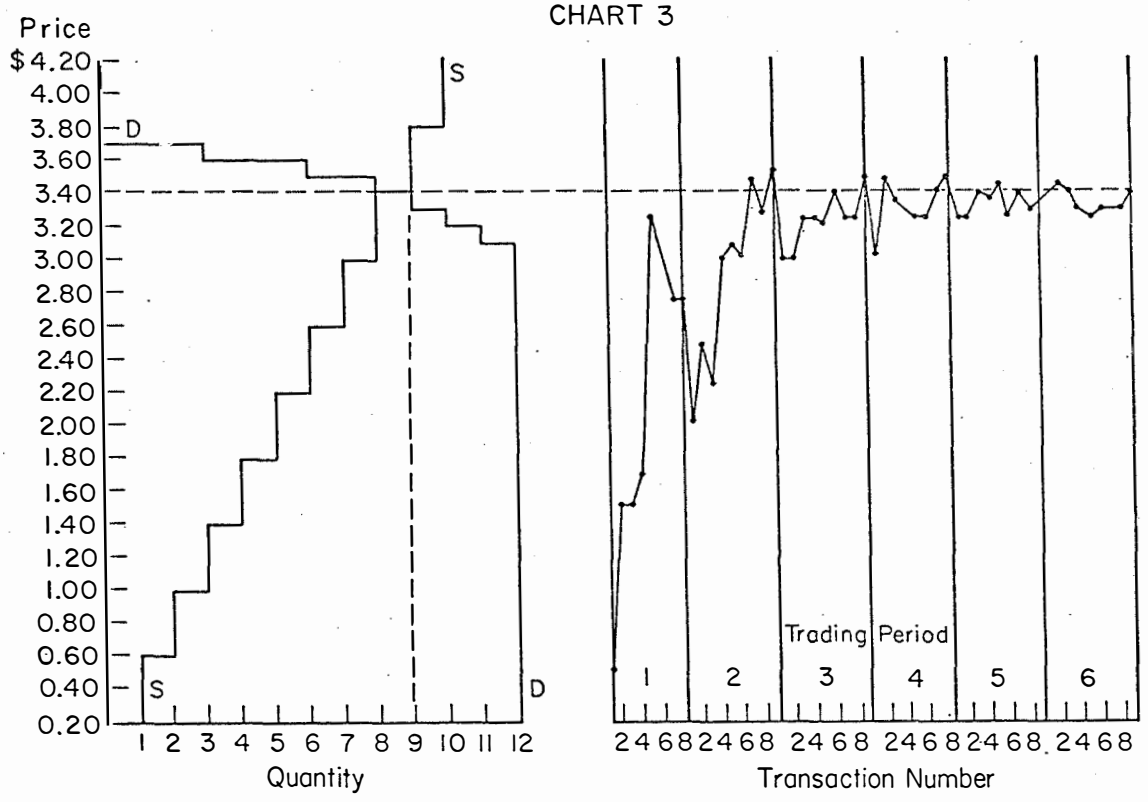

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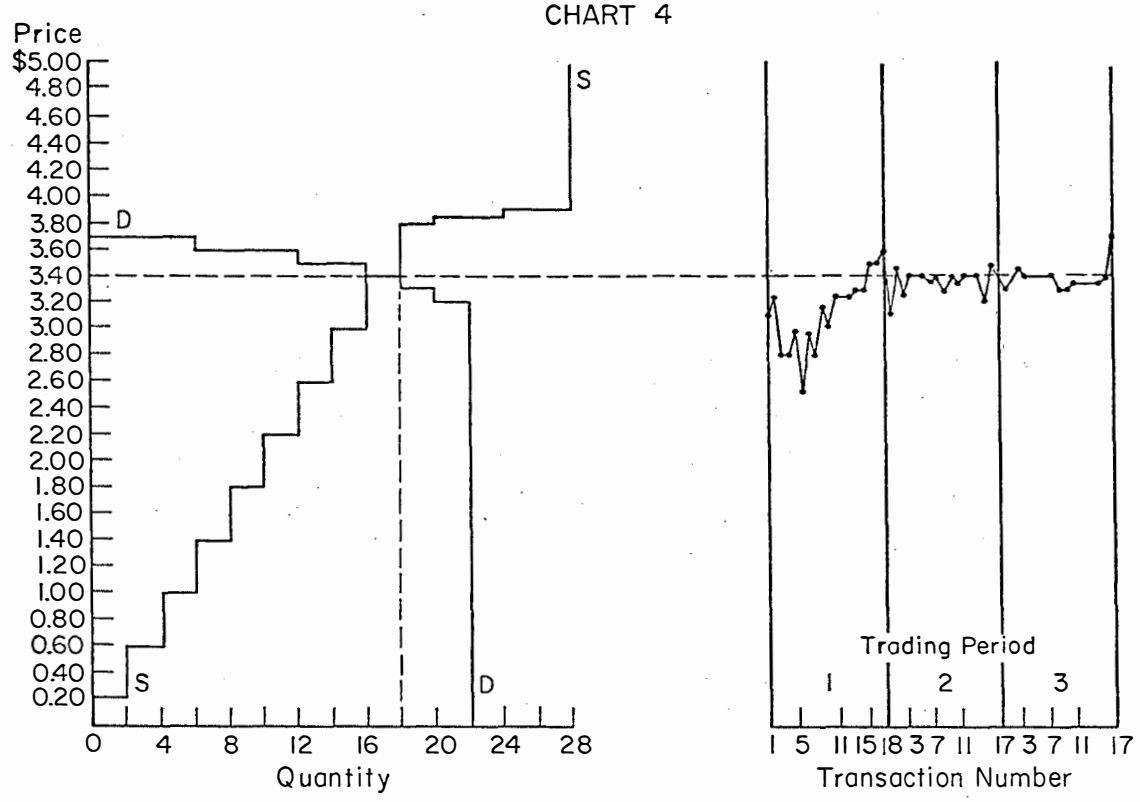

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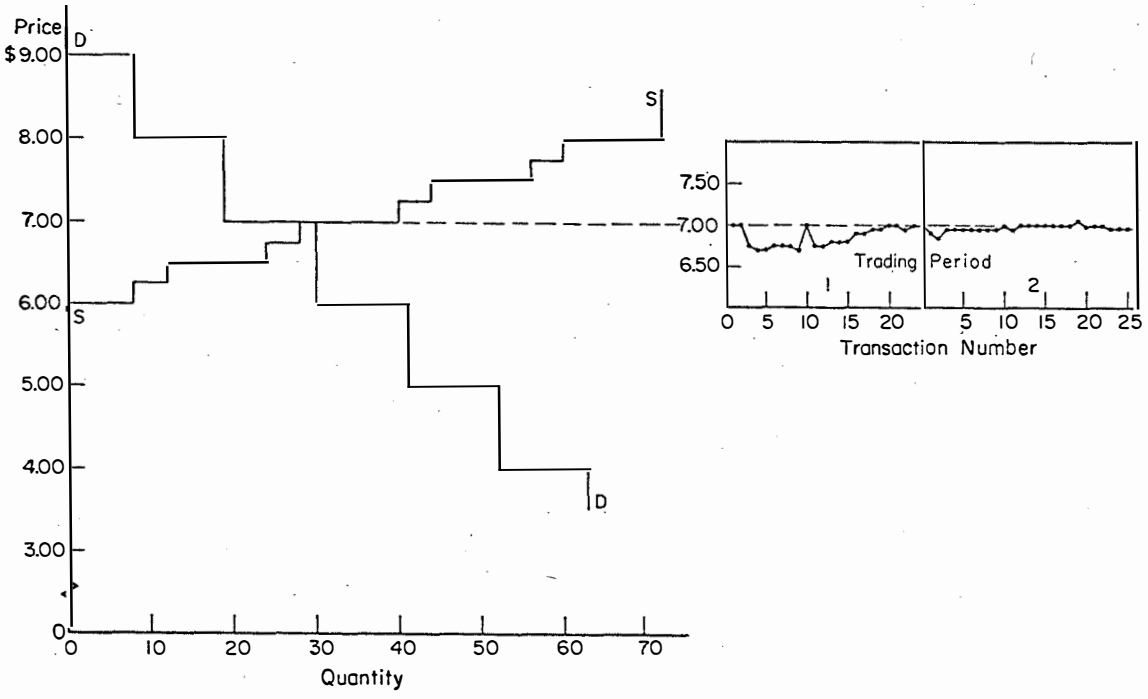
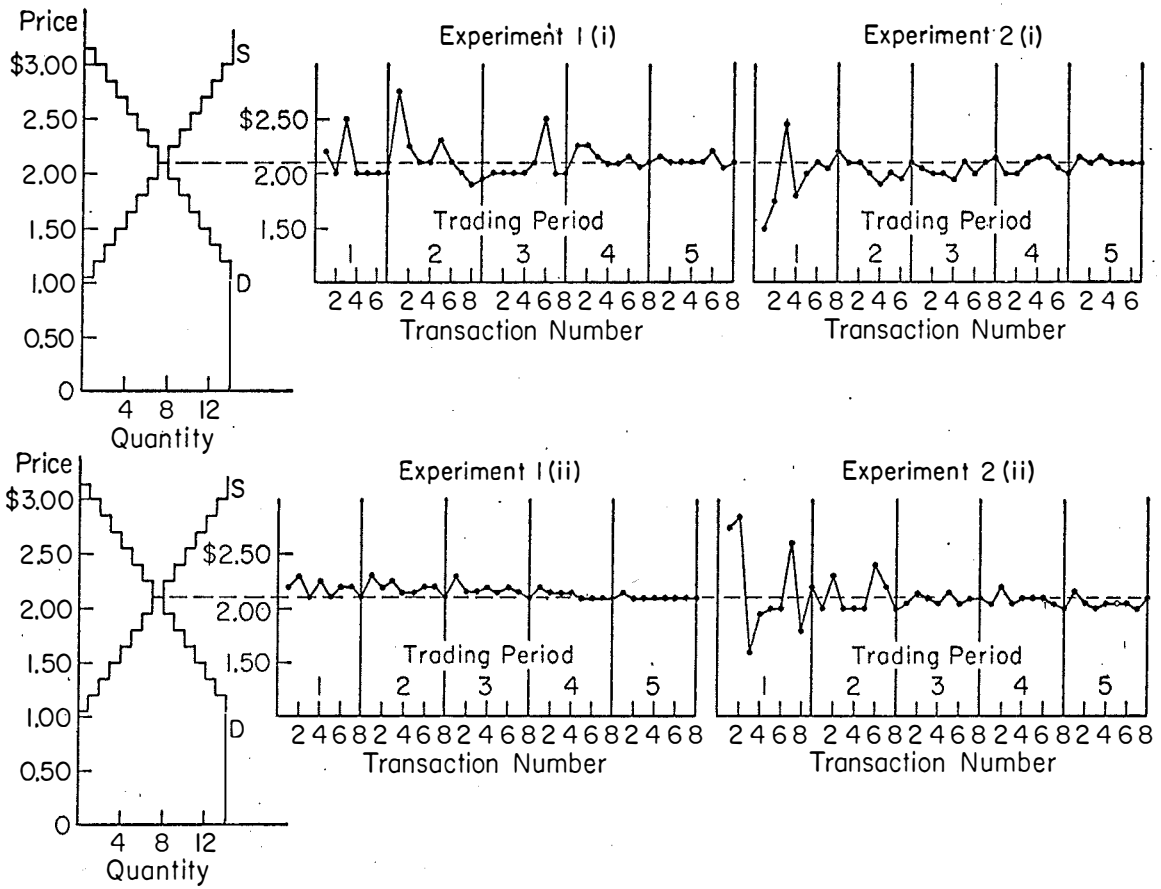


CHART 6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1.00
0.50
0
S
D
4 8 12
Quantity
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Experiment 2 (i)
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2.00
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Trading Period
1 2 3 4 5
Transaction Number
Experiment 1 (ii)
Experiment 2 (ii)

CHART 7

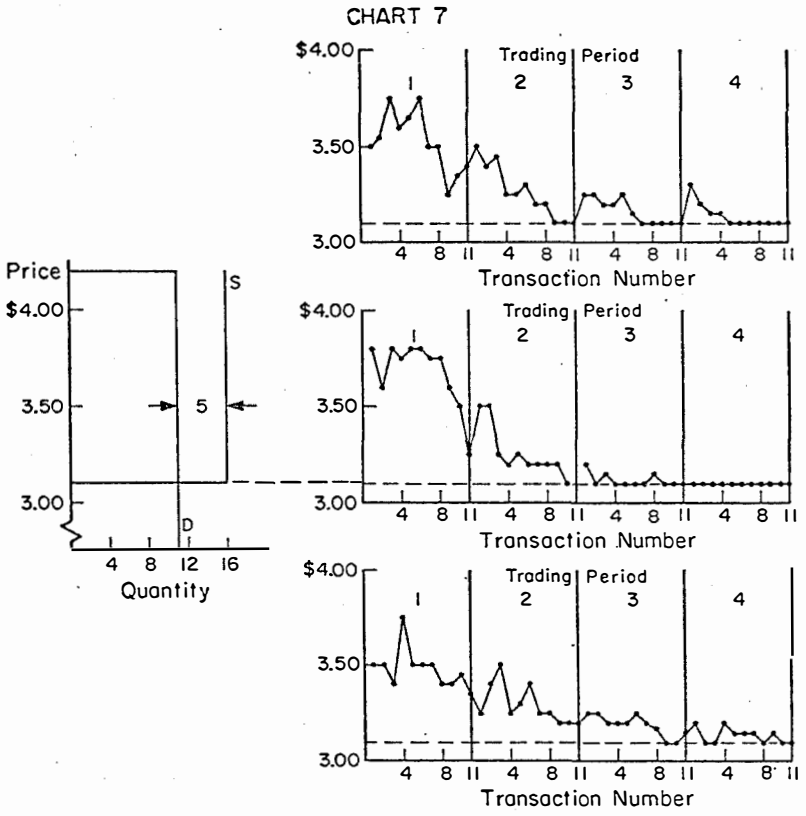


CHART 8

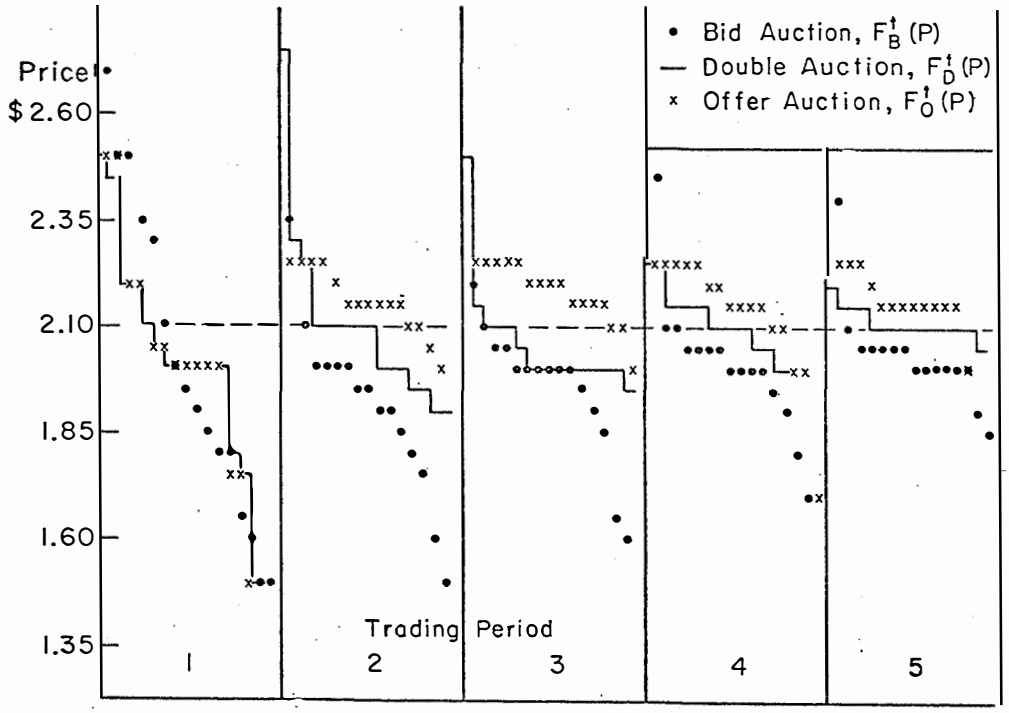
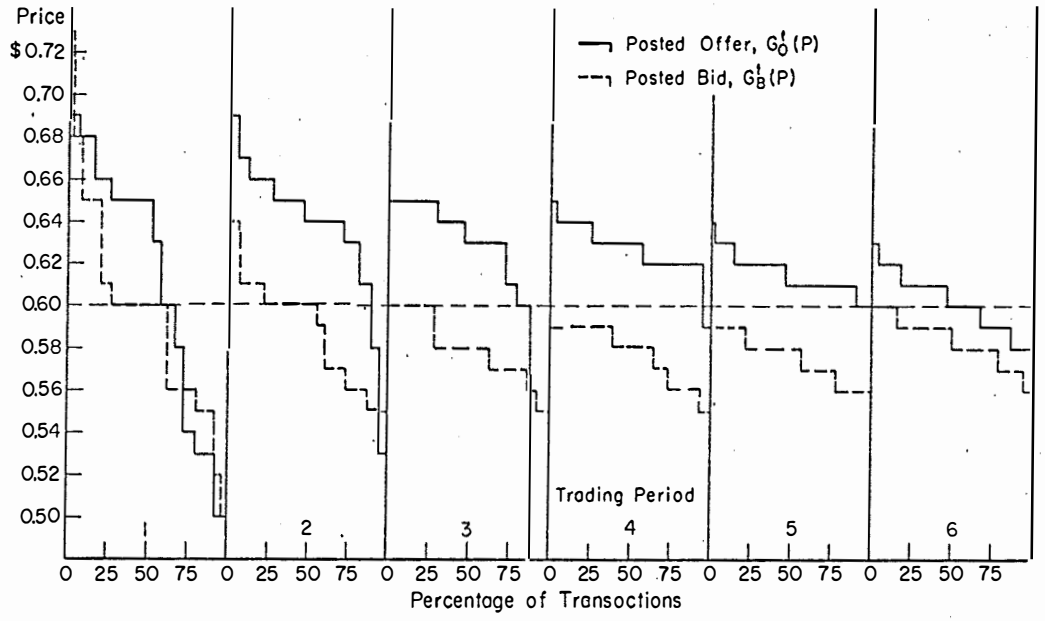


CHART 9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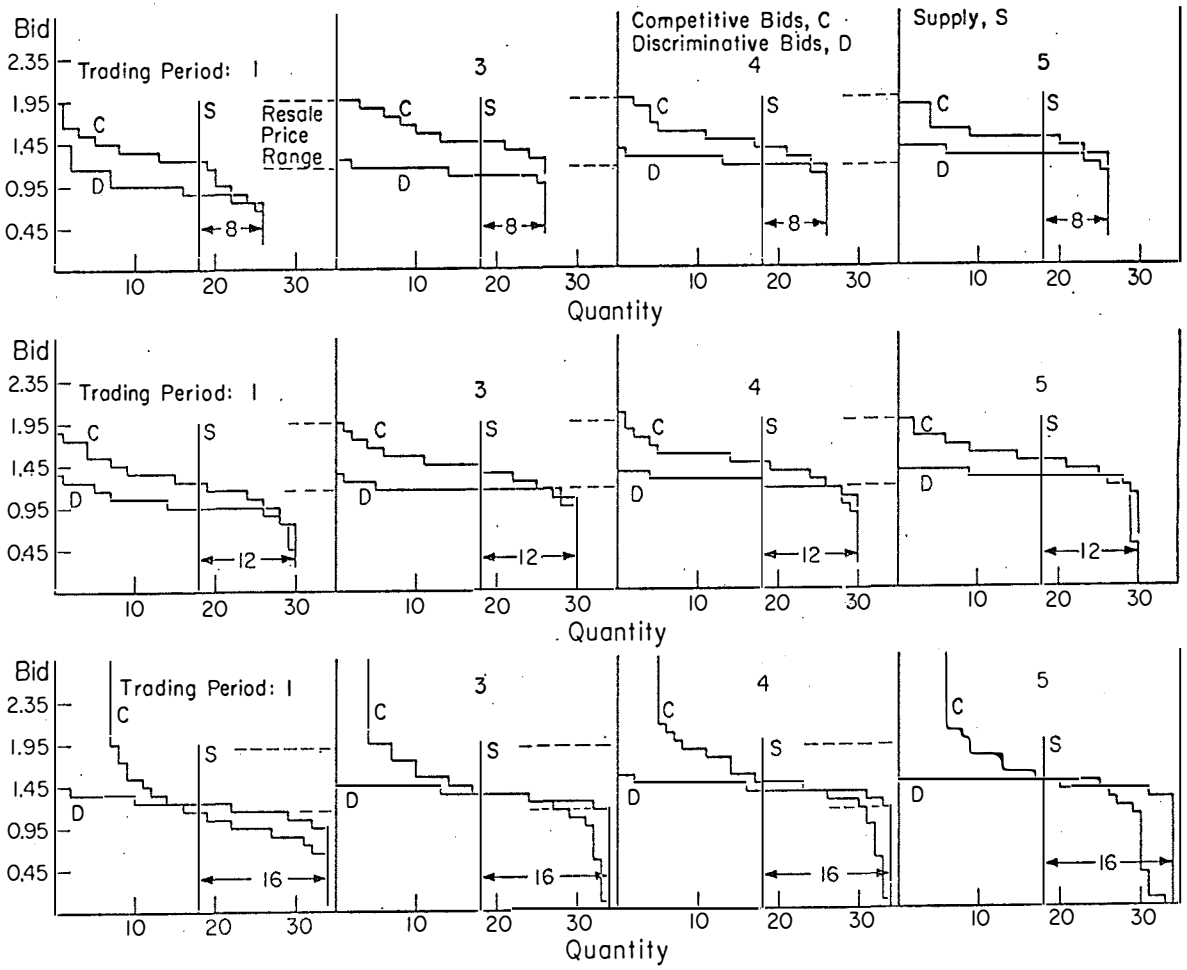
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
0.50
Posted Offer, $G_O^t(P)$
Posted Bid, $G_B^t(P)$
Trading Period
1
2
3
4
5
6
0 25 50 75 0 25 50 75 0 25 50 75 0 25 50 75 0 25 50 75 0 25 50 75
Percentage of Transactions

CHART 10


Bid
2.35
1.95
1.45
0.95
0.45
Trading Period: 1
3
4
5
Competitive Bids, C
Discriminative Bids, D
Supply, S
Resale Price Range
C
D
S
8
12
16
10
20
30
Quantity

FOOTNOTES

1. Charts 1 - 4 are reproduced from Smith (1962). Chart 5 reports a previously unpublished experiment.

2. The second and third experiments in Chart 7 are reproduced from Smith (1965), while the first is previously unpublished.

3. Experiments 1(i) and 2(i) are reproduced from Smith (1964), while 1(ii) and 2(ii) are previously unpublished.

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