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Industrial Organization Theory And Experimental Economics

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THE INTRODUCTION of laboratory experimentation in economics was motivated by theories of industrial organization and market performance. The first published market experiments were those of Edward H. Chamberlin (1948). He explored the behavioral characteristics of markets he described as being "purely" but not "perfectly" competitive and he thought that the principles of monopolistic competition would be more useful than the textbook theory of demand and supply in explaining the observed behavior. Austin C. Hoggatt (1959) and Heinz Sauermann and Reinhard Selten (1959) both focused on markets with three competitors and independently provided the first experimental evidence that the Cournot model might be a reasonably accurate description of oligopolistic behavior. Oligopoly and bilateral monopoly motivated the classic work of Lawrence E. Fouraker and Sidney Siegel (1963) which introduced several of the techniques still used today. Vernon L. Smith's (1962) sensitivity to the organization of the U.S. security industry led him to the fundamental discovery that the law of competitive demand and supply can be observed operating in an experimental environment. The field of experimental economics has experienced substantial evolution during the intervening twenty years. This paper is an attempt to provide an introduction to the methods and an assessment of available results which might now be useful to the students of industrial organization.

The paper has six sections. Section I outlines some of the step-by-step details of laboratory procedures. Sections II through IV summarize experimental results. In Section II markets with several participants are analyzed and compared to a competitive model. Section III summarizes monopoly results. Section IV, which is the longest, deals with oligopoly. This organization of the material is natural from the point of view of traditional theory, but the organization is not necessarily natural from the point of view of results.

As will become evident from the following pages, market institutions have a substantial influence on performance and this influence sometimes outweighs the importance of market concentration and relative firm size. Consequently, on occasion it is easier to organize and summarize results according to market institutions as opposed to numbers, size, or other economic parameters.

The fifth section addresses the obvious question regarding the relevance of laboratory methods. Section V outlines several common criticisms of experimental methods, which define both the limitations and the qualifications that must accompany conclusions drawn from experimental evidence, and discusses them in terms of results. The recent explosion of professional interest in experimental methods reflects, in part, a recognition that experimental methods provide a source of shared experience for scholars who are developing and evaluating theories about complicated, naturally occurring processes. While laboratory processes are simple in comparison to naturally occurring processes, they are real processes in the sense that real people participate for real and substantial profits and follow real rules in doing so. It is precisely because they are real that they are interesting. General theories must apply to special cases, so models believed to be applicable to complicated naturally occurring processes should certainly be expected to help explain what occurs in simple, special-case laboratory markets. Theories which do not apply to the special cases are not general theories and thus cannot be advocated as such.

I. *Laboratory Market Details*

Real markets are easy to create. The difficult part is creating a market that demonstrates a point which remains valid upon replication in other subject pools and by other experimenters. Because we now know that market behavior is sensitive to both individual preferences and to the details of the structure of the institutional arrangements, the experimenter must avoid contaminating these variables with poorly developed experimental procedures. If the experimental procedures do not control these variables adequately, attempts to replicate the results may fail because the experimenter has unknowingly failed to conduct the same experiment. This section is a brief outline of the procedures, methods, and measurements.

A. *Market Creation*

The key economic variables in all markets are the value individuals place on the object being transacted, and the form of the market organization within which buyers and sellers interact. Preferences are induced by a special application of derived demand theory called induced preference theory (Smith, 1976b; Plott, 1979). The theory takes advantage of the fact that principles of economics apply to all commodities which are valued independently of the source of individual values or the ultimate use to which the commodities are to be put. In an experimental market subjects normally trade a commodity such as a chit of paper that has no intrinsic or use value. The commodity is given value by the experimental rules governing its creation by sellers and redemption value by buyers. Buyers make money by buying from sellers and reselling to the experimenter according to a predetermined redemption value schedule. The difference between the purchase price and redemption value is profit, which is the buyer's to keep. Sellers make a profit by purchasing units from the experimenter at a predetermined cost schedule and selling to the buyers. The difference is a profit which the seller keeps. In addition to these profits, participants sometimes re-

ceive a small commission for each trade. The role of the commission will be explained below.

The idea is deceptively simple. The key assumptions are that an individual prefers more money to less, has no attitude toward the commodity or situation other than the advantages created by potential resale, and that the individual fully understands the terms of resale. If these conditions hold, the redemption and cost schedules are limit price schedules for the subjects. The first column of Figure 1 contains an example of what buyers typically see. Row 1 shows the redemption value of the first unit this individual purchases during a period. The purchase price is entered in row 2, and the profit and profit plus commission are entered in rows 3 and 4 respectively. As can be seen, these entries are made for each purchase during a period.

Neglecting the commission for a moment, the incentives of individual i can be represented by a total revenue function $R^i(x_i)$ indicating the revenue generated by a quantity of purchases x_i. The magnitude $R^i(x_i) - R^i(x_i - 1)$, the redemption value for the x_ith unit can be seen as a limit price function. In the example shown in Figure 1 it is negatively sloped, but of course the slope as well as the pattern of such redemption value functions across agents are parameters under the control of the experimenter. Under competitive assumptions this redemption value schedule is the individual's inverse demand schedule. Thus the experimenter, by varying these parameters, can control demand elasticity, market concentration, and other magnitudes of economic interest.

Incentives of suppliers are induced in a similar manner. The second column in Figure 1 demonstrates the technique for a typical individual supplier. Row 2 contains the cost of the first unit sold. This cost is incurred at the time of the sale. When the sale is made, the seller enters the selling price in the first row and then calculates the profits and profit plus commission as directed by rows 3 and 4. The profit from other sales made during this period is similarly calculated. Thus, individual i has a cost function $C^i(x_i)$, and the marginal cost, $C^i(x_i) - C^i(x_i - 1)$, has already been calculated for the individual as shown on the forms. The shapes of the cost functions across sellers determine supply elasticity, concentration and entry, and are controlled by the experimenter.

At the top of Figure 1 you will notice a period indicator. Experimental markets are usually conducted over a series of periods or "trading days." The length of a period is normally from five to fifteen minutes depending upon the volume of activity anticipated. Unless the commodity has some explicit properties of an asset which has a life over time (Robert Forsythe, Thomas R. Palfrey, and Plott, 1982), each period is like an independent trading day with demands, supplies, profit potential, etc., independent of (but possibly identical with) those of previous periods. It is well established that trading patterns change as the market days are replicated. No good model of this dynamic exists but, as will be demonstrated below, the market equilibration process occurs with the replication of market periods.

Whether an individual is shown the redemption value for all periods at one time or just for one period at a time varies according to the purpose of the experiment. In many cases the individual knows his/her own redemption values for all periods at the beginning of the experiment, but there are important exceptions. If individual costs or redemption values are changing each period, for example, these would be revealed one at a time just before a period began. In almost all experiments the individual knows only his/her re-

Redemption Values

Individual Buyer Number _____

Period _____

Unit	Row		Value
1	1	1st unit redemption value	$2.00
	2	purchase price	
	3	profit	
	4	profit + 15¢ commission	
2	5	2nd unit redemption value	$1.50
	6	purchase price	
	7	profit	
	8	profit + 15¢ commission	
3	9	3rd unit redemption value	$1.00
	10	purchase price	
	11	profit	
	12	profit + 15¢ commission	
4	13	4th unit redemption value	$ .75
	14	purchase price	
	15	profit	
	16	profit + 15¢ commission	
5	17	5th unit redemption value	$ .25
	18	purchase price	
	19	profit	
	20	profit + 15¢ commission	
		Total period earnings	

Costs

Individual Seller Number _

Period _____

Unit	Row		Value
1	1	selling price	
	2	cost of 1st unit	$ .25
	3	profit	
	4	profit + 15¢ commission	
2	5	selling price	
	6	cost of 2nd unit	$ .75
	7	profit	
	8	profit + 15¢ commission	
3	9	selling price	
	10	cost of 3rd unit	$1.00
	11	profit	
	12	profit + 15¢ commission	
4	13	selling price	
	14	cost of 4th unit	$1.25
	15	profit	
	16	profit + 15¢ commission	
5	17	selling price	
	18	cost of 5th unit	$1.75
	19	profit	
	20	profit + 15¢ commission	
		Total period earnings	

Figure 1. Redemption and Cost Incentive Forms

demption value and nothing about the redemption value of others.[1] The procedures and instructions are designed to keep this type of information private.

Commissions are not always used. It is known that individuals tend not to trade units unless there is some advantage for doing so. The function of the commission is thus to induce marginal trades by overcoming what seems to be a small transactions cost (Plott and Smith, 1978). Subjects are instructed not to trade at prices which are above (below) redemption values, thus avoiding the problem of including the commission as part of the limit price. More recent experimentation has dropped the use of commission and avoided the "marginal trade" problem by adjusting the market parameters to allow for some gains from trade at the margin.

The institutional organization of a market has been an important treatment variable. The mechanics of how buyers and sellers get together can substantially influence market performance. That is, for the same underlying incentives, the market performance is affected by a change of institutions. For example, the original experiments by Chamberlin (1948) had the agents circulating in a room and privately negotiating price when a buyer or seller was contacted. In some of these markets terms of trade were publicly displayed on the blackboard as they were consummated, while in others they were not. This market behaves much differently than, say, an oral double auction. In an oral double auction all bids and offers are orally tendered and publicly displayed, and only one outstanding (the last, the best, etc.) bid and offer open at any time. Sellers (buyers) are free to accept an outstanding bid (offer) by a public, verbal indication. Thus, in the oral double auction, all bids, offers, and contracts are public information.

Much of traditional industrial organization theory was developed to meet a need for understanding economic processes in which the market institutions themselves are endogenous. Questions regarding market conduct, market practices, cartel development and evolution are all of primary importance, but they have not yet been addressed by experimentalists who, with very few exceptions, have tended to treat institutional variables as exogenous. Such decisions by experimentalists reflect, in part, a need for more theory about the creation and evolution of market institutions.

Five prominent forms of market institutions have been studied in the experimental literature: (a) auction markets, (b) posted-bid (offer) markets, (c) negotiated-price (telephone) markets, (d) markets with price protection and advance notice policies, and (e) sealed-bid (offer) markets.

Actually, the listing of only five different types involves an oversimplification. Each of these types can be subdivided further into special types. Auction markets, for example, can be either English or Dutch according to whether the prices start low and are bid up by competition or start high and are reduced until some competitor accepts. English auctions can be "oral double" or "one-sided." Markets differ according to whether or not the terms of contracts are public and the sequence in which bids, offers, and terms become known. The possibilities are so numerous that it sometimes seems more appropriate to think in terms of a continuum rather than fixed classes. For example, posted-price auctions look very similar to "sealed-bid" auctions if sellers must post prices without the knowledge of the prices of other sellers and without the ability to im-

[1] Only one market experiment has allowed such complete information and it did not converge as expected (Smith, 1981). Bargaining experiments reported in Alvin E. Roth, Michael W. K. Malauf, and J. Keith Murnigham (1981) also suggest that models must be modified in the presence of an informational environment in which all monetary values are known by all agents.

mediately "adjust" prices in light of the competition.

B. *Laboratory Procedures*

The experimental procedures are one of the most important aspects of an experiment. The wording and the format of the instructions in most experiments have evolved so that very little about them is arbitrary or has escaped careful scrutiny. This extreme care is dictated by two overriding concerns. First, the procedures must be formulated so that other researchers, when following them, will be able to replicate reported results. The heart of the experimental method is replication and the procedures embody the operational content of many of the parameters and experimental conditions which, if changed, may induce different results. If results are to replicate with different subject pools and different experimenters, then the procedures must be carefully considered. Secondly, there is a widespread belief that experimenters will or can influence the behavior of subjects by subtle suggestion about what the experimenter wants to demonstrate. Whether this belief is well founded is open to question,[2] but regardless of the answer the procedures must minimize the potential for such influences if the results are to be taken seriously by a large number of people.

Each of the procedural steps is subject to experimental control. Typically, subjects are recruited by announcements in class, bulletin boards, or newspapers.[3] Once subjects are assembled, the instructions are read and questions answered. Sometimes a practice period, or period zero in which no money is at stake, is conducted. The technology used during the experiment is dictated by many considerations including availability. Many experiments simply utilize a classroom with a chalkboard to record trades. Faculty offices and the connecting telephone system, the word processing system from typing pools, and even special electronic equipment designed for the experiment have been used. The most fully automated experiments are those using an interactive computer system called PLATO which allows subjects to be located in different cities (Arlington W. Williams, 1980). Because computerized procedures involve high setup costs, they are typically not used to explore radically new (from an experimentalist's point of view) forms of market institutions and organization.

The Appendix contains sample instructions for posted-price markets and for oral auctions. Notice that subjects are not told to maximize or to make as much money as possible. Furthermore, words like "competition," "maximizing," "collusion," "coalition," etc., or other words which might suggest to the subject some theory or expectation on the part of the experimenter, have been carefully omitted. The examples used to illustrate accounting conventions and profit computations are standard across many different experiments. In fact, attempts are made to maintain—across vastly different types of experiments (e.g., committees vs. markets)—as much of the wording and examples as possible in order to minimize the latitude for theories which seek to explain the results of a particular experimental series in terms of the language used in the instructions for that series. The instructions make clear the opportunities available to the subjects, but the motivation is supplied by the people.

The procedures can differ according to the purposes of the experiment. For exam-

[2] A possible example within the framework reviewed in this paper is explored in Linda Cohen, Michael E. Levine, and Plott (1978). The case is one in which the subjects in a committee experiment evidently thought they were to provide insights for marketing strategies and ignored the incentive system in an attempt to do so.

[3] Sample announcements can be found in Elizabeth Hoffman and Plott (forthcoming).

ple, marginal values are displayed in Figure 1 as opposed to total values so subjects need not compute the former in making decisions. It was done for them. The individuals take tests at the end of the instruction period to see if they can read these tables as hypothesized. After each of the first several periods, each individual's accounting is checked to see if there is any misunderstanding about the reward structure. Questions about the mechanics of calculating profits are welcomed and answered fully and openly. Yet, if someone asks, "What am I supposed to do?" the experimenter rereads the relevant portion of the instructions: "The experimenters do not care whether or how you participate so long as you stay within the confines of the rules." Presumably, if the capacity of an individual to understand or to recognize a reward structure was a variable to be studied as part of the market, then all of these procedures should possibly be changed, but for most of the experiments reviewed here this was not an objective.

Some of the procedures are adopted to allow individuals as much "independence" from the social situation as possible. Social security numbers and names (both of which are used as receipts for the monetary payments) are collected after the experiment is over. Individuals are paid in private so others need never know their earnings. When individuals are obviously confused or are having difficulty with the instructions, efforts are made to avoid any embarrassment. Commodity names or references to "similar" types of natural situations (stock markets, automobile industry, etc.) are usually not used in order to avoid giving some impression about how individuals are expected to act.

The level of incentives is typically somewhat above the hourly wage for the subject pool. For upper class undergraduate or graduate students the expected earnings are in the eight to ten dollars per hour range if the models are reasonably accurate. Employed adults participating at night or on weekends would earn more. Sometimes a flat payment, promised as a minimum in order to attract subjects, is paid at the beginning of the experiment in addition to money earned during the experiment.

From a pragmatic point of view experimentalists realize that their experiments will be checked by other researchers. Such researchers may have a vested interest in having the results *not* replicate. This is especially true in fields like industrial organization in which the data can become part of an adversary process. An unambiguous and complete set of experimental procedures is an important source of protection.

C. *Performance Measures*

Price patterns, volume, distribution, and market efficiency are variables of obvious interest. Usually price is measured as the average of contract prices during a period but sometimes it means the last contract in a period. Volume and income distribution are easily observed.

Efficiency as introduced by Plott and Smith (1978) is more subtle, but the reader should note that it is exactly the traditional consumers' plus producers' surplus notion. In market experiments the system attains an efficient (Pareto optimal) allocation if and only if the subjects as a group maximize the total monetary payments from the experimenter. Thus, the relative efficiency of systems is determined by comparing the total payment to subjects with the maximum possible total payment.

In order to demonstrate how this measure of efficiency is related to ideas of consumers' plus producers' surplus, consider Figure 2. Assume the economy has two demanders, numbered 1 and 2, and two suppliers, numbered 3 and 4. The demanders are identical and each has the redemption values shown in Figure 1. The

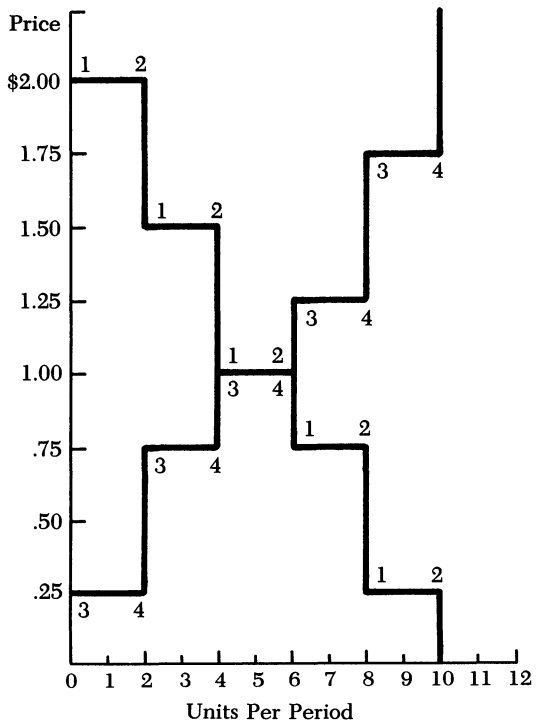


Figure 2. Aggregated Limit Values

suppliers are also identical and each has the marginal cost schedule in Figure 1. The market demand function is obtained by adding the (inverted) individual limit price functions, and the market supply is obtained by adding the (inverted) individual marginal cost functions. As can be seen, consumer plus producer surplus is maximized at six units with each buyer (seller) buying (selling) three (three) units. A quick check indicates that this allocation also maximizes total subject profits from the experiment. If, for example, another unit was purchased, the subjects' payment to the experimenter (marginal cost) would exceed experimenter payment to the subjects (redemption value) on this unit. Total profits would thus be decreased.

A typical market inefficiency would be of the following sort. Individual 3 from Figure 2 sells four units and individual 4 sells one. Exactly why and how this might occur is, of course, material for the field of industrial organization. From Figure 2 one can see that individual 3's fourth unit should have been excluded from the market because its cost is greater than the marginal benefit. Furthermore, individual 4's second and perhaps third unit should have been included in the market because the marginal social benefit was no less than the cost of these units.

The efficiency measure must be interpreted with some care. In some studies the commissions are included as part of the measure while in the other studies they are not. Including them makes the measure sensitive to whether or not the marginal (zero profit) traces are made, thereby capturing one aspect of efficiency.[4] On the other hand, the commission seems to have no natural economic interpretation.

The efficiency measure is also sensitive to the shapes of the curves as are all surplus measures. Suppose, for example, the first unit redemption values are increased by a factor of ten and the first unit marginal costs are reduced to zero. Because these units will almost surely trade and now constitute a large proportion of the surplus, the system efficiency would increase for any expected pattern of trading. Thus, by adjusting the level of the base profit potential with intramarginal units that will almost certainly trade, the absolute efficiency levels can be influenced.

A similar possibility exists with the allocation of redemption values across individuals. Suppose the two redemption values of $.75 were held by a third and fourth individual who have the right to buy only the one unit. If either of these two individuals make a trade, efficiency drops. Since they have only one (inefficient) unit to trade, they stand ready to trade and will trade should the price *ever*

[4] Notice that without a commission the marginal trades under the conditions of Figure 2 may not be made. There are no gains from an exchange of the third unit of one and three for example.

"wander" down in that range. Thus, these units seem to have more opportunity to be traded than when they are held as the fourth unit by the original two traders. In the latter case, inefficient trading can occur only if the price wanders low enough *after* an individual has traded three units.

Other special problems with efficiency measures occur in the case of uncertainty. Thus far, experiments involving risk have had only a limited relevance to the industrial organization literature and will not be reviewed here (Plott and Shyam Sunder, 1982). The important point is that comparisons of efficiencies across markets with different economic parameters must be treated with care. If the underlying economic parameters are held constant and the institutions alone are changed, the efficiency comparison has a more solid basis.

II. *Competitive Market Models*

A. *Auction Markets*

The competitive model seems to work best when markets are organized as oral double auctions. Oral auction markets are characterized by public bids (offers) to buy (sell) units and the freedom of any participant to accept terms which (s)he wishes. Several variants exist depending upon the length of time or circumstances under which a bid (offer) remains outstanding, whether the bid (offer) is made orally or logged through a computer, the roll of the specialist's "book," etc.[5]

The overwhelming result is that these markets converge to the competitive equilibrium even with very few traders. Figure 3, which shows the price of every sale in the order in which it occurred, is typical. Each period represents a market day with a given demand and supply. The competitive equilibrium is \$2 with a volume per period of eight contracts. As market days are replicated under identical conditions, prices tend to converge to the competitive equilibrium. Efficiency levels tend to converge to near 100 percent. If a change in parameters occurs, such as a shift in demand or supply, the prices converge to the new equilibrium after two or three periods.

As long as the industrial structure has a few buyers and sellers, these convergence and efficiency properties appear to be independent of the basic economic conditions. Different shapes of demands and supplies as systematically examined by Smith (1962, 1965, 1976a) yield no substantial differences. The variations explored covered various cases of demand elasticity and nonlinearity. In Smith (1965) a completely inelastic (in the relevant range) demand was used along with a fixed supply (greater than the quantity demanded). In all cases, after a few periods, the market performance was close to that predicted by the competitive model.

Basic economic conditions do seem to influence the direction of convergence to equilibrium, and thus the distribution of income and profit. The path to equilibrium seems to be from above (below) if consumer's (producer's) surplus is greater than producer's (consumer's) surplus (Smith and A. W. Williams, forthcoming). Thus, one might expect that markets with relatively steep demands and reasonably flat supplies, record somewhat elevated profits for the sellers relative to the competitive equilibrium. These profits would accrue at disequilibrium trades and so the phenomenon would also be accompanied by falling prices. If the industry has been

[5] Typically bids are tendered verbally. An auctioneer, upon hearing a bid (offer) writes the bid (offer) and the index of the agent on the chalkboard. The bid (offer) is repeated verbally and the floor is then open for new bids and offers. Only the last bid and offer are standing and they remain standing until accepted, cancelled or replaced. Under "New York rules" a replacing bid or offer must be an improvement upon the standing bid or offer. Acceptance can occur at any time.

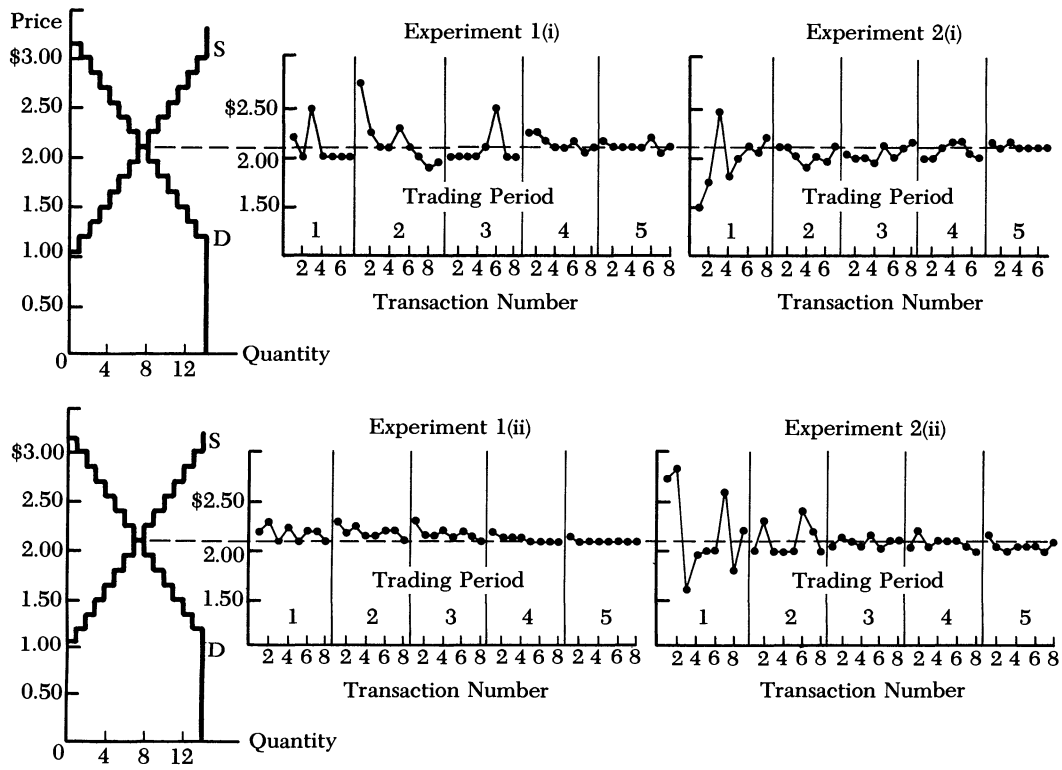


Figure 3. Oral Double-Auction Markets

Source: Smith (©1976a, New York University, Chart 6, p. 53. Reprinted by permission of New York University Press.)

characterized by unanticipated demand or supply shifts, prices and profits can be affected. Adjustment to a new equilibrium takes time, and profits or losses can certainly reflect disequilibrium trades. To date only one study has attempted to characterize the dynamic adjustment path (Smith, 1965) and the conclusions from this are clouded by the fact that the choice of the estimation technique affects the conclusion regarding which dynamic adjustment theory Smith's data support (Forrest D. Nelson, 1980). No compelling theory of dynamic adjustment exists, and experimental studies have not yet explored the influence of basic economic conditions on adjustment paths sufficiently to provide any further generalizations.

Figure 4 has been added to show a typical adjustment path for an oral double auction when producer's surplus is greater than consumer's surplus. The path is from below. If the relative surpluses were reversed, the approach, according to currently accepted hypotheses, would be from above. The key parameter is the surpluses, however, and not demand or supply slopes, although in the case of linear functions these are obviously closely related.

Changes in the market institutions are known to influence price and profit patterns. For example, oral double auctions

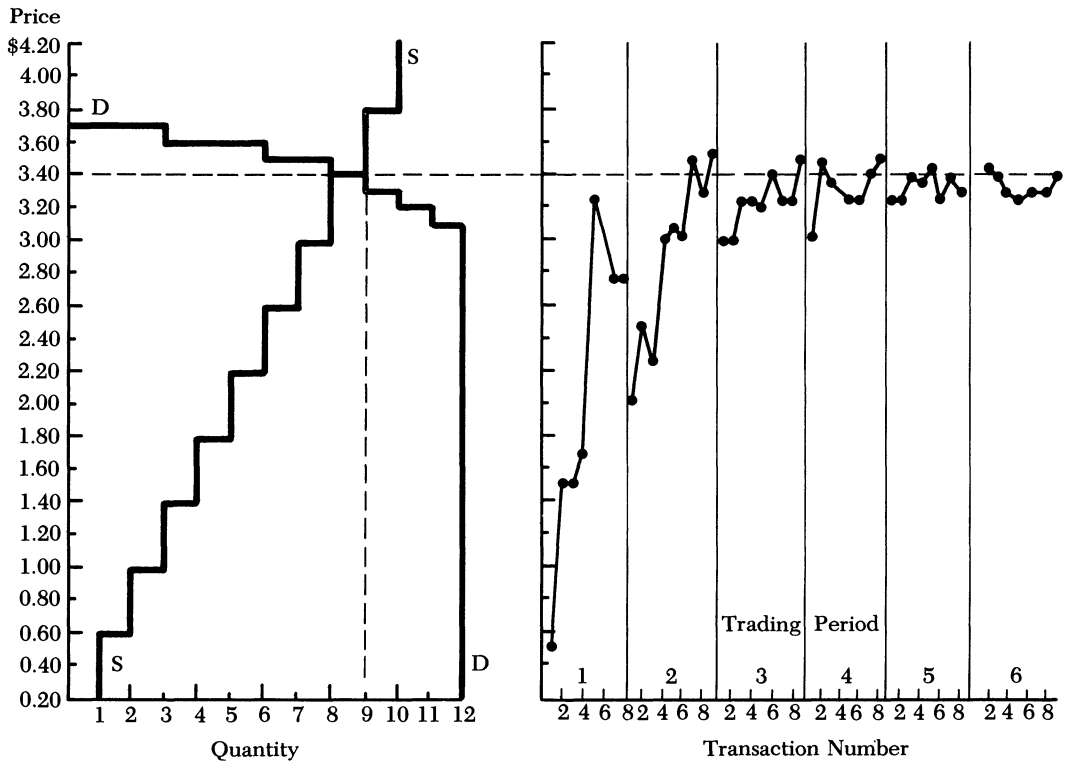


Figure 4. Oral Double-Auction Market

Source: Smith (©1976a, New York University, Chart 3, p. 50. Reprinted by permission of New York University Press.)

conducted by computer can affect the speed of convergence especially with inexperienced participants (A. W. Williams, 1980). However, the most dramatic differences in behavior within the class of oral auction institutions occurs with the one-sided auctions. The approach to equilibrium is from above (below) if the auction is a one-sided bid (offer) auction. If buyers (sellers) can bid (offer) while sellers (buyers) must accept or reject without making counter offer (bids), then the approach is from above (below). The distribution of income is against the side which articulates the terms (Smith, 1964; Plott and Smith, 1978). That is, if buyers bid while sellers make no counter offers, the distribution goes against the buyers. Exactly why this occurs is not known but some sort of "counterspeculation" seems to be occurring and both the dynamics and the performance seem to be very similar to the Dutch auctions to be described later. The "accepting" side of the market seems to anticipate as a group the potential for increased (decreased) prices as buyers (sellers) bid (offer) in competition among themselves. Even though a precise theoretical model does not exist, notice the implication of the result. Sellers who face an oral auction institution would prefer that the buyers bid. To the extent sellers can organize themselves to compete by accepting favorable bids and not

making counter offers, the approach to equilibrium and thus profits will be influenced in their favor. Similarly, markets organized as oral offer markets may have some use as tools to counteract "unjustified market power" of sellers. It is important to note, however, that the nonmonopolized one-sided oral auctions examined to date have all been nearly 100 percent efficient. The institution affects only the distribution of income.

The range of market structures that has been systematically explored is not wide because the results under the oral auction institutions examined thus far appear to be almost independent of market structure. Experiments with three and four sellers converge with regularity to the competitive equilibrium. If influences from market structure exist for nonmonopolized markets under the oral double auction, they are not so pronounced as to be easily detectable.

The performance of the oral double auction has stimulated two important types of basic research. The first is to gain some understanding of the process which guides the market to near the competitive equilibrium (David Easley and John O. Ledyard, 1980; C. B. Garcia, 1981). The second is to design institutions which are even more efficient than the oral double auction (Smith et al., 1982; Patrick Joyce, 1981). Perhaps as the first task advances, the second task will be easier.

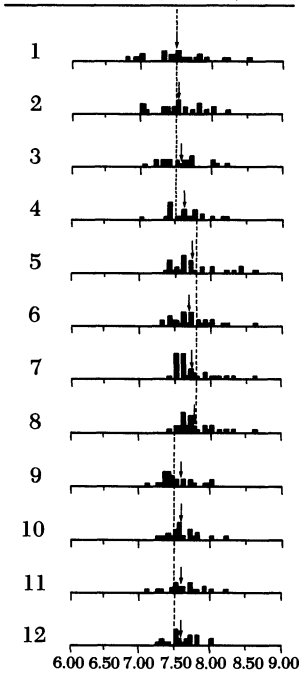
B. *Negotiated Prices (Telephone Market)*

Negotiated price markets are those within which the terms of trade are privately negotiated with each transaction. Experimentally these conditions have been implemented through a telephone system where buyers and sellers, each located in a separate office, negotiate privately by telephone. Buyers and sellers can call each other and discuss terms and/or agree on a contract price. Contact among buyers or among sellers is usually prevented so that information about prices is not public. Buyers can shop among sellers, shopping costs are low (in some experiments advertising is permitted), and shopping and negotiating are the only sources of information.

The first experiments of this kind were done by James T. Hong and Plott (1982). The distribution of prices from one such experiment is shown in Figure 5. As can be seen, the system begins with a wide variance in prices. Evidently some buyers are just better negotiators than others but the source of this (dis)advantage, whether they shop more (less), or make more (less) credible promises or threats, etc., is unknown.

With time the variance shrinks. The mean price approaches the competitive equilibrium. When demand shifts (periods 5 and 9) the prices approach the new equilibrium. Efficiency in these markets is in the 80 to 90 percent range as shown in the figure. Volume in the Hong and Plott experiments is greater than the competitive equilibrium volume. This result, when combined with those of Chamberlin (1948), suggests that poor information may result in sales exceeding the competitive equilibrium.

Only two different industrial structures have been explored within this market institution. The Hong and Plott study had eleven buyers of about equal size. The 22 sellers ranged from relatively large (the five largest firms had 60 percent of the market) to relatively small sellers, some of whom should not be able to make transactions according to the competitive model because their costs were above the competitive equilibrium price. The price-time series shows that the competitive model is a reasonably accurate predictor of equilibrium, but some marginal sellers were able to sell at prices above the competitive equilibrium price to buyers who were evidently poorly informed or did not choose to shop.



Period	Price: Competitive Equilibrium	Price: Actual Average	Price: Standard Deviation	Volume: Competitive Equilibrium	Volume: Actual	Efficiency
1	$7.50	$7.51	$.416	21	25	83.0%
2	7.50	7.53	.332	21	24	88.9
3	7.50	7.57	.296	21	23	90.1
4	7.50	7.63	.280	21	22	89.2
5	7.80	7.75	.347	27	28	87.7
6	7.80	7.71	.293	27	30	87.3
7	7.80	7.74	.281	27	30	90.1
8	7.80	7.77	.265	27	30	95.8
9	7.50	7.59	.210	21	23	96.2
10	7.50	7.60	.226	21	23	95.8
11	7.50	7.61	.253	21	22	94.8
12	7.50	7.59	.206	21	23	94.3

Figure 5. Telephone Market

The second study by David M. Grether and Plott (1981) examined telephone markets with two large sellers (each with 35 percent of the market) and two small sellers (15 percent each). Sellers in the experiment even had accurate knowledge of the market demand functions. The average prices, shown in Figure 6, are typical of the general results. Similar to the Hong and Plott results, prices initially have a high variance. With time, variance is reduced and the competitive equilibrium is approached.

A third study by Heinz Jürgen Crössmann (1982) was not a telephone market. Individual negotiations took place in private booths. Prices and other terms of contracts were strictly private information, so information was less available than in telephone markets in which several shopping calls could be made easily. Multiple-unit or block trades were possible. Sellers were required to make binding quantity decisions prior to the opening of a market period. On average, prices were near the competitive equilibrium relative to the predictions of other static models. The smooth adjustments toward the long-run competitive equilibrium are not always present, and in some markets the movement is away from the long-run equilibrium. However, in these cobweb, unsta-

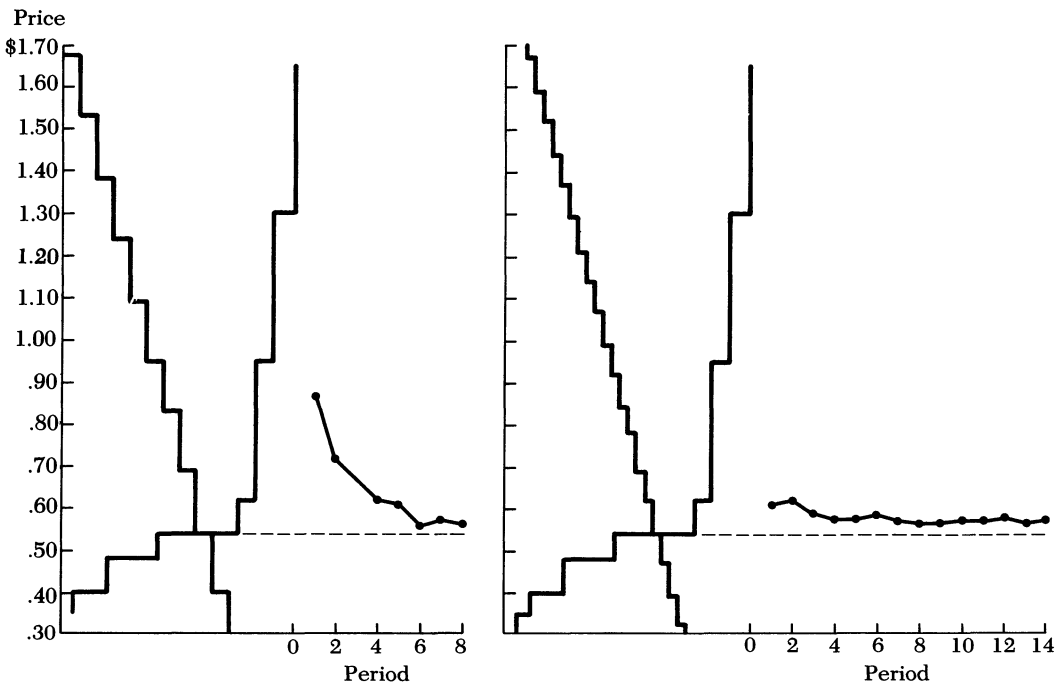


Figure 6. Average Price Per Period for All Periods in Two Markets

ble markets there exist no pronounced cycles.

C. *Posted Prices*

In posted-price markets all prices are public and no discounts are made from the posted prices. Furthermore, posted prices are changed only after some period of advanced registration. In experimental markets the institution is implemented as follows. The posting agents decide between market periods what price to post in the next period. Each agent makes a private pricing decision and submits the price to the experimenter. After collecting the prices the experimenter announces all prices, and the market opens. No price changes from posted prices are allowed during a period.

The posted-price institution has received more scholarly attention than any other. Frequently, however, those conducting the research did not view themselves as engaged in a comparative institutional analysis. The original duopoly experiments of Hoggatt (1959) and of Fouraker and Siegel (1963) can be interpreted as posted-price institutions as can almost all "market games" and "prisoner's dilemma" experiments. Nevertheless, it was not until 1978 (Plott and Smith) that it became recognized that the posted-price institution has its own independent effects.

Two generalizations seem possible at this time. First, posted-offer (bid) markets tend to have higher (lower) prices than do oral double auction markets in that the adjustment to equilibrium tends to be from above (below) and either converges to equilibrium more slowly or does not converge at all. Secondly, efficiency tends

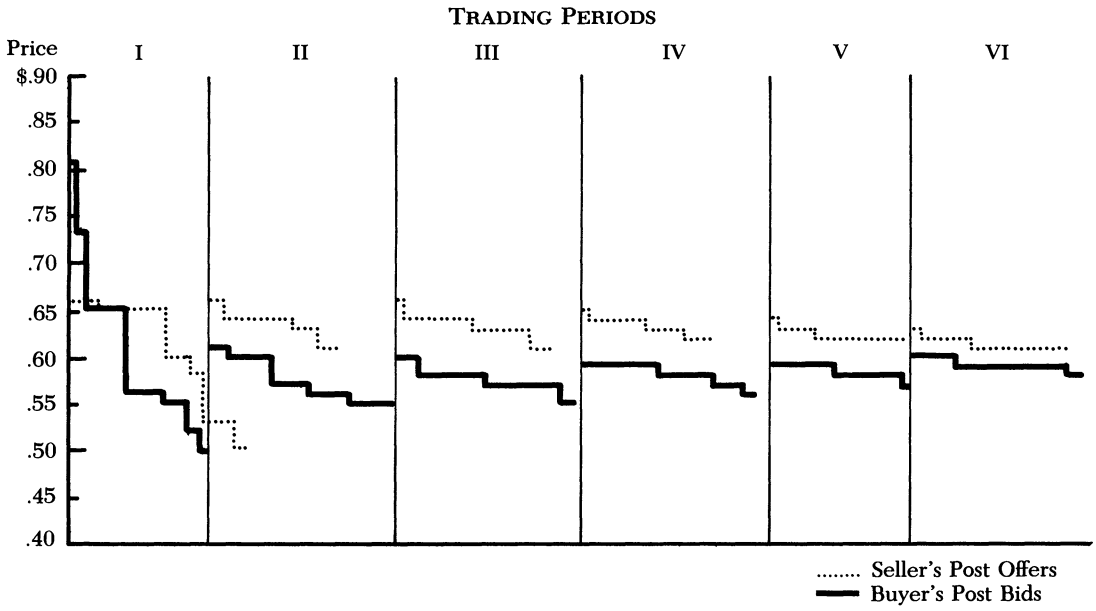


Figure 7. Williams' Results: Cumulative Distribution of Trades with Multiunit Incentives*

* The figure represents for each price p*, the volume of trades which took place at a price $p \geqq p^*$.
Source: Plott and Smith (1978, p. 135).

to be lower in the posted-price markets than in the oral double auctions.

These tendencies were first observable in experiments run by Fred Williams (1973) who incorrectly thought they were due to the fact that his traders could buy or sell more than one unit. Previous experiments were oral auctions in which each subject could trade only one unit. Williams was interested in traders who controlled multiple units, but in moving from one type of incentive structure to the other he also changed the market institution. The results of two of his experiments are shown in Figure 7. These show the cumulative volume of trades at each price (e.g., the curve indicates the number of trades at price P or above). Prices at first are removed from equilibrium ($.60), but with time they converge closely to it. Whether or not posted-price markets ever stabilize at the competitive equilibrium is an open question since not all posted-price markets exhibit such monotone behavior as those in the figure. Certainly convergence does not occur within the number of periods that produce convergence in oral auctions.

The Williams results were replicated by Plott and Smith (1978), who also demonstrated by conducting multiple units, oral auction markets, that the market institution and not multiple units is the cause. The possible importance of basic market conditions and market structure under posted prices is investigated in Hoffman and Plott (1981) and Hong and Plott (1982). In the former, posted prices in markets with storage and speculation were studied. In the latter the experimental market had thirty-three sellers, as opposed to the four in all other experiments.

The two generalizations were observed to hold in all cases.

The Plott and Smith experiments and many subsequent experiments allowed buyers to withhold purchases and play favorites to encourage low prices. Some of the Williams experiments used a computer to stimulate demanders according to the following strategy: first, purchase from the low-priced seller all s(he) wished to sell, and then move to the next low-priced seller, continuing until excess demand is exhausted. One of the principal discoveries of Plott and Smith was that their demanders behaved passively (or purely competitively), almost exactly like the Williams computer. This suggests that one of the major features of the posted-price market is that the "power" of the nonposting side is somehow eliminated. Intuitively, when facing posted prices, abstinence from purchases (sales) is unlikely to produce more favorable terms because once the price is posted it cannot be changed until after the period is over. The buyer anticipations, gaming, and/or "counterspeculation" conjectured as important in explaining the behavior of one-sided oral auctions seems to be absent in one-sided posted-price markets.

D. *Multiple Markets and Endogenous Qualities*

Experimental research on multiple markets which interact sequentially or simultaneously has proceeded slowly because they are difficult to control and they are time consuming. For example, a multiple market experiment can easily require three hours.

In the first multiple market experiment (Ross M. Miller, Plott, and Smith, 1977) each of two markets could be interpreted as a season with the possibility of carry forward and speculation. Production in period A could be carried forward to period B. The competitive model is an accurate model of the market behavior. The results have been replicated by A. W. Williams (1979), Hoffman and Plott (1981), and Plott and Jonathan T. Uhl (1981)[6] and extended to include autarchy markets, posted prices, and middlemen. The same general framework has been modified to study rational expectations models as applied to the behavior of a two-period asset and a futures market (Forsythe, Palfrey, and Plott, 1982). Four simultaneous and interdependent (complements) markets have been studied in connection with the problem of allocating scheduled landing rights at the major airports (Grether, R. Mark Isaac, and Plott, 1979; 1981). In all cases multiple markets are observed converging to predictable equilibria, and the efficiency levels of the entire system are in the upper 90 percent.

Two studies can be interpreted as bearing on the issue of endogenous products or product quality. The first was not motivated by industrial organization at all but by the rational expectations models of finance and the possibility that securities markets are capable of transferring information about an underlying state of nature possessed by "insiders" to other, uninformed participants in the market (Plott and Sunder, 1982). The experiments convincingly demonstrate that this can occur. The relationship with industrial organization arises because the results can be interpreted as demonstrating the possibility that product quality, as determined by an underlying state parameter, can be revealed to the uninformed through the competition among those who are informed. It is as though consumers buy from retailers who buy from a common producer but have different information about product quality.

The second study was motivated by the

[6] This study involved a slight variant of the oral double auction. Bids and offers were left open until accepted or changed. Thus, the market institutions were similar to an oral double auction with limit orders and an open book.

market for physicians' services, automobile mechanics, insurance, etc. (Plott and Louis L. Wilde, forthcoming). In all cases the consumer must rely on the information possessed by the seller who may not have an incentive to tell the truth. The markets were constructed to perform poorly according to the predictions of the standard models because the information transmitted was likely to be inaccurate. The major result was that the markets failed to fail. The "lemons" phenomenon or "overselling" of profitable services characteristic of market failure theory, was not observed. In fact, buyers did better by relying on the advice of sellers than they did when they were trained to make their own diagnosis. The authors conjectured that the cause of so much "truth" was the search behavior of buyers. With search a seller may conclude that the best policy is to give the buyer the same information that was given by the other sellers in hope that the buyer will believe the seller, stop searching, and make a purchase. Each seller, believing other sellers are offering "good" advice, then would have an incentive to do the same. This is purely conjectural, however, and the theory explaining the performance of this market remains an open question.

III. *Monopoly*

Two different types of monopoly experiments have been conducted. The first, and possibly the most relevant for industrial organization theorists, is a market that has a single seller with a variable supply. In the second case, a single seller has a fixed supply which is to be auctioned or otherwise completely sold according to some type of competitive bidding process.

A. *Variable Supply and Contested Markets*

The difference in market performance under oral auctions, as opposed to posted prices when there are several sellers, leads naturally to an inquiry about the case of a single seller. Monopoly experiments under both institutions (Smith, 1981; Smith and A. W. Williams, 1981a) provide a dramatic demonstration of the importance of both market structure and the institutional environment in determining market performance.

Monopoly can definitely cause prices to diverge from the competitive equilibrium. However, when the market is organized as an oral double auction, the standard monopoly model does not do so well. There is a strong tendency for prices to erode away from the monopoly equilibrium price. On occasion, in Smith's experiments the prices actually approached the competitive equilibrium. The data are sufficiently mixed and the number of observations are so small that we cannot determine which model, the monopoly model or the pure competitive model, will be the easiest to modify to capture the behavior for monopolized oral double auctions. Figure 8 reproduces the time series from a particularly interesting experiment. It illustrates the difficulty of reaching any general conclusions about the comparative accuracy of the models. Prices start high near the monopoly price, erode to the competitive equilibrium, return to the high levels, and begin to erode again. For the most part volume is closer to the monopoly level of five than to the competitive level of eight units. This interesting behavior seems to be attributable to the considerable power of buyers in this institution. Perhaps by "counterspeculation" they tend to withhold purchases and force prices down when facing a monopolist. Exactly what coordinates this action is unknown (these buyers cannot communicate except through bids and offers) but, as will be shown below, certain institutions seem to prevent it and therefore help the monopolist.

In contrast, in posted-price (offer) mar-

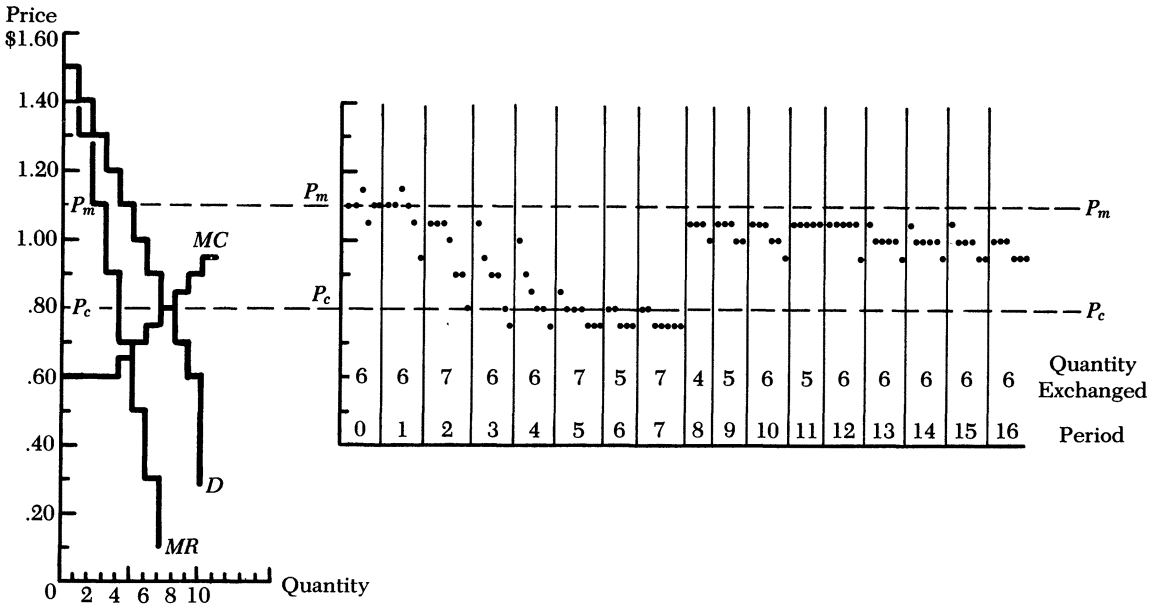


Figure 8. Double-Auction Monopoly

P_m = monopoly price
P_c = competitive price
Source: Smith (©1981, Purdue Research Foundation, Chart 3, p. 91).

kets a different picture emerges in the case of monopoly. When the monopolists post prices, market behavior is more accurately captured by monopoly theory. The results of one experiment are in Figure 9. This monopolist adjusts prices to measure demand. The measurements are accurate because under the posted prices the effects of buyer "counterspeculation" seem not so severe and so demand gets revealed at each price.[7] The monopolist ascertains the profit at each price, sets price at the monopoly level, and leaves it there. Volume stays at the monopoly level.

Compared to the oral auction, the posted-offer markets tend to be mechanical. These data suggest that monopolists have a vested interest in having some variant of posted-offer institutions. Of course the dual is that customers would prefer the oral double auction or the posted-bid institution, both of which result in lower prices in experimental markets. Obviously such results are not sufficiently well understood to serve as the sole basis for public utility regulation reform but they certainly suggest some hitherto unappreciated potential for market institutions in this regard.

A limited study of natural monopolies by Don Coursey, Isaac, and Smith (1981) provides new evidence that "contestable" markets might also provide a form of market control of monopoly. Ten markets were created, each of which had declining costs conditions theoretically sufficient for the emergence of natural monopolies. Supply technology at the individual firm

[7] I do not intend to imply that "counterspeculation" is absent.

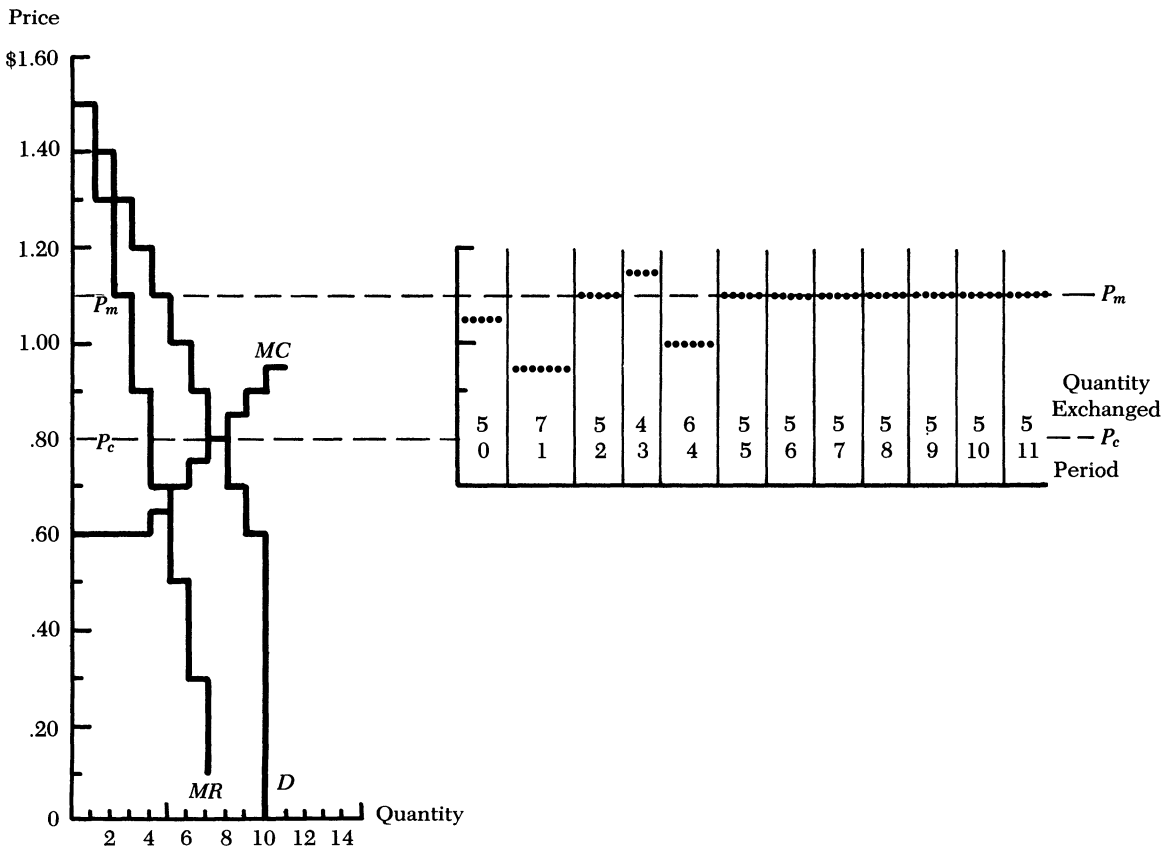


Figure 9. Posted Offer Monopoly

P_m = monopoly price
P_c = competitive price
Source: Smith (©1981, Purdue Research Foundation, Chart 5, p. 93).

level was such that marginal and average costs declined for ten units, after which further increased supply was impossible.

Demand price was above average cost through the tenth unit where it was $.12 above the average cost of a firm producing ten units and $1.00 below the average cost of a firm producing one unit. A monopolist would theoretically provide six units. Cooperating duopolists without side payments would provide two units each. Price was above marginal cost at the eleventh unit. The market demand was generated by five equal-sized but not identical buyers. Units were "sold to order" with no fixed cost, setup cost, or inventories.

Four of the ten markets were supplied by a single monopolist. The other six had two potential and identical suppliers. Each supplier posted a price at the beginning of the period and a nonzero quantity. The market institution required the seller

TABLE 1
PARAMETERS AND DATA FROM PROTECTED MONOPOLY AND CONTESTED MONOPOLY

	Parameters		Period 18 of All Markets	
Variable	Monopoly Model	Competitive Model	Protected Monopoly (Average from Four Markets)	Contested Monopoly (Average from Six Markets)
Price	$1.12	$0 to $.12	$1.05	$.182
Quantity	6	10	5	9.3
Efficiency	60%	100%	49%	85.5%

Source: Coursey, Isaac and Smith (1981).

to sell to all buyers requesting units at the posted price until the posted quantity was exhausted, whereupon the seller could sell no more. The posted prices were publicly announced and buyers, given random access to the market, were free to choose the seller they wanted. Purchases were known only to the buyer and seller involved.

The results are in Table 1. As can be seen, the behavior of the posted monopoly is modeled by the monopoly model rather than the competitive model. Coursey, Isaac, and Smith conjecture that the error of the model is due to buyer "counter-speculation." The six markets with contestable monopolies were more accurately modeled by the competitive model. In contestable markets monopoly actually existed in all but ten of the one hundred six total number of periods observed. The monopolist changed from period to period, however, depending upon which potential supplier posted the lowest price.

These results are only an initial probe into the behavior of contestable markets. Clearly the contestants have an interest in mechanisms which would restrict the quantity that each offered to the market. Perhaps by implementing institutions or practices which make the quantities submitted public, along with the market demand function and individual sales volumes, sellers will be able to coordinate decisions in a tacit collusion. Obviously such open questions can be addressed by further experimentation.

B. *Fixed Supply*

Industrial organization theory has traditionally been focused on the case of variable supply. Such focus is understandable because if the supply is fixed, the efficiency implications of monopoly are nonexistent. In the absence of price discrimination, a monopolized market with a fixed supply is exactly like a competitive market according to textbook theory. Nevertheless, the fixed supply case is of interest. It is one part (marketing the supply) in a two-part (determining supply) monopoly decision process. Moreover, fixed supplies (or demands) and competitive bidding are frequently used by government to allocate public resources (e.g., oil leases) or to procure public goods (e.g., weapons).

The first sealed-bid experiments with many bidders were conducted by Smith (1967). These experiments were motivated by a controversy about the marketing of United States Treasury bonds. The Treasury uses a sealed-bid discriminative auction. If Q units are to be sold, they are sold to the Q highest bidders at a price

equal to the bid. Critics of the Treasury believed that a sealed-bid one-price auction would generate more money. In the one-price auction the Q units are sold to the Q highest bidders, but all bidders would pay the same price and this price would equal the Qth highest bid or the $(Q + 1)$th highest depending upon the rules. A more recent problem regarding methods of allocating the right to land at four of the nation's busiest airports again focused research on the properties of these two type of auctions (Grether, Isaac, and Plott, 1981).

Smith examined a market in which lotteries were auctioned. Meyer W. Belovicz (1979), using this same type of market, explored extensively the principal hypothesis which emerged from Smith that the relative revenue-generating capabilities of the two auction institutions depended critically upon the magnitude of excess demand. The results emerging from that study are mixed.

The methodology was changed in Gary J. Miller and Plott (forthcoming) and in James C. Cox, Smith, and James M. Walker (1981) to one in which the personal value of the object was known with certainty but the value to other bidders was unknown. In the G. J. Miller and Plott study, bidders could purchase more than one unit, aggregate demand was stationary for many periods (but subject to an occasional shift), and individual demands were rotated each period in a manner which preserved aggregate demand but changed each individual demand. In the latter, bidders could purchase only one unit, redemption values were generated randomly each period, and only the discriminative auction was studied.

Both of these studies provide support for Nash equilibrium bidding models when there are several (three or four) bidders; that is, an equilibrium identified as one in which each individual is optimizing given the actions of every other individual. The G. J. Miller and Plott study suggests that the relative revenue-generating capabilities of the two types of auctions depend upon demand elasticity with discriminative auctions generating more revenue when demand is relatively inelastic and one-price auctions generating more revenue when demand is relatively elastic. In part, this is due to the weight of "disequilibrium" auctions. After convergence takes place, they generate about the same revenue. These results are replicated in the study by Grether, Isaac, and Plott (1981).

Figure 10 taken from G. J. Miller and Plott (forthcoming) illustrates the point. The limit price function is the curve LOL. The Nash equilibrium bidding curve is the line POL for the discriminative auction and it is LOL for the one-price auction when there is some uncertainty. The actual bids for the first period under a discriminative auction are as shown by dd. Under one-price auctions the distribution of bids is about the same for the first period. Under the one-price auction the distribution of bids approaches the limit price function LOL after several periods so the price is P. The distribution of actual bids under the discriminative auction in the tenth period is shown. Since the area A is greater than the area B, the revenue under the discriminative auction is greater in this period.

Single unit auctions have been the subject of several papers. The market structure differs from the studies above in that individual valuations are drawn at random each period so that the market demand as well as individual demands are not stationary. The market institutions examined are the English auction, the Dutch auction,[8] first price sealed-bid auction, and the second price sealed-bid auction. Theo-

[8] Prices start high and move downward in fixed intervals. The bidder who first stops the downward price movement purchases the object at the price.

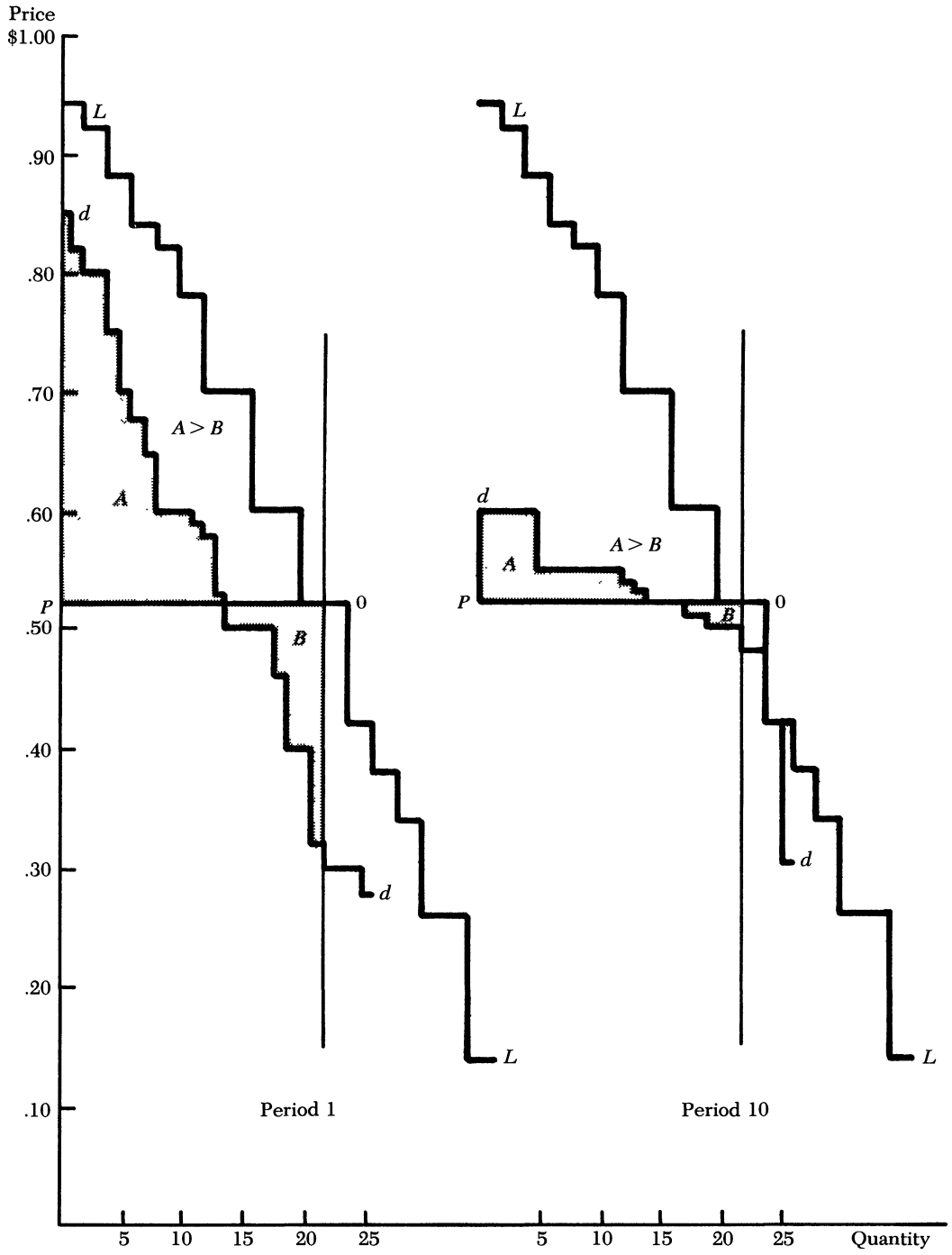


Figure 10. Demand and Revealed Demand in a Discriminative Auction

Source: Miller and Plott, forthcoming.

retically (Nash bidding hypothesis) the English and the second price auction are equivalent and the Dutch and the first price auction are equivalent in terms of prices and efficiency. Many experiments with these auctions (Vicki M. Coppinger, Smith, and Jon A. Titus, 1980; Cox, Bruce Roberson, and Smith, forthcoming) indicate that the English and second price auctions behave substantially the same, and prices and efficiencies of these two exceed those of the other two. The Dutch and first price auction are not the same, with prices and efficiency of the latter greater. Cox, Roberson, and Smith are able to reject the hypothesis of Nash equilibrium behavior with identical utility functions and have been exploring the applications of models with variable risk preferences.

The exploration of sealed-bid institutions is initiated along a different dimension by Thomas R. Palfrey (1981; forthcoming). The question is whether a monopolist who has several different objects to sell by a first price sealed-bid auction is better off by selling them separately or by bundling them together and selling the packages. With few bidders, bundling is profitable, but as the number of bidders increases, the advantage of bundling over separate auctions decreases.

IV. *Oligopoly*

A polar case of cartel theory is monopoly, so in a sense the results of a perfectly functioning cartel were reviewed in the previous section. A principal conclusion was that the performance of a monopoly (perfect cartel) market is substantially affected by the marketing institutions. Because this result carries over so strongly to the case of "imperfect" cartels, the review is organized according to the market institutions as opposed to other variables such as number of agents in the market, the size of agents, or demand elasticity.

A. *Oral Auction Markets*

Within oral auction markets two types of situations have been studied: an "obvious" harmony of interest and explicit conspiracy. Market participants almost always recognize a harmony of interest and this recognition can be identified in the market signals which occur almost constantly in oral double auctions. After a contract, when the market is open for bids or offers, the bidding will sometimes start with a clearly unacceptable bid or offer (e.g., a bid of one cent or something far below any previously accepted price, or an offer from two to ten times higher than any previously accepted price). Such bids (offers) are often followed by similar bids (offers) from other buyers (sellers) who are indicating a willingness to keep offers low (high). When this happens, the other side of the market tends not to be passive. Such "outrageous" terms are frequently answered by equally ridiculous terms from the other side which is indicating that it too has that strategy available. Even when there is no answer, the terms of such high bids or offers are not accepted, as the other side simply waits (counterspeculates). Competition slowly works the terms into the previously accepted range. Signals such as these never seem to work to affect prices in the double auction institution or if they do the effectiveness is not immediately obvious.

In some experiments a harmony of interest is easily recognizable. In studies by R. M. Miller, Plott, and Smith (1977); F. Williams (1973); and Hoffman and Plott (1981) the markets had two speculators who could purchase units in one period (period A) and sell them in the next period (period B). These two individuals were the only agents who had the ability to buy units and carry them forward. They had a clear interest in maintaining a low price in period A and a high price in period B. In spite of this recognizable interest

and the fact that only two agents had such powers, the market behavior is modeled well by an intertemporal competitive equilibrium.

The point is made somewhat more forcefully in Plott and Uhl (1981). In these markets four middlemen had the capacity to buy in one market in which they were the only buyers and sell in a physically separated market in which they were the only sellers. Unlike the speculation experiments in which all participants heard all bids, offers, and contracts, in the Plott and Uhl markets the initial sellers were one group of people who saw the action in the primary market and the final purchasers were a different group of people who saw only the action in the secondary market which was physically removed from the first. Both the harmony of interest and the collective power of the middlemen were obvious, but explicit conspiracy was not possible since middlemen were never allowed to speak directly to each other. Nevertheless, the competitive model fits the data closely.[9]

In two studies, focal points were given the opportunity to operate as collusive devices. In R. Mark Isaac and Plott (1981b) and in Smith and A. W. Williams (1981b) price ceilings (floors) were imposed slightly above (below) the equilibrium. A theory is sometimes advanced (Frederic M. Scherer, 1970, pp. 179–82) that such controls act as a focal point and thereby facilitate tacit collusion. In the oral double auction markets reported in these studies there is absolutely no support at all for the theory that nonbinding controls operate that way. If anything, the *opposite* is true. A ceiling (floor) that is nonbinding according to competitive theory tends to lower (increase) prices.

Private, pre-period meetings by one side of the market were studied by Isaac and Plott (1981a) as a facilitating practice under the oral double auction institution. Four sellers (buyers) were allowed to talk freely between periods, while the buyers (sellers) left the room to get the next period's demand (cost) functions. Side payments and profit sharing were not allowed and discussions of such schemes were prohibited.

The study asked the following questions: Do traders discuss collusion when given the opportunity? Can the traders formulate some sort of agreement? Once formulated, do they stick to it? Can the consequences of the conspiracy be detected in the market performance?

The answer to the first two questions is yes. These traders discussed conspiracy almost immediately and they had no difficulty in articulating an agreement. The answers to the second two are not without qualification. Data in Figure 11 provide a comparison with the oral double auction when no collusion is present (the first three experiments, I.P.I, I.P.II, and I.P.III) with those in which there is a seller's conspiracy (the fourth and fifth indexed as I and II) and a buyer's conspiracy (the sixth and seventh indexed as III and IV). The top charts are the average prices each period. The middle charts are the per period volumes, and the bottom charts are the efficiencies.

In order to see the effects, it is important to notice the near monotone convergence of *all three* measures in the first three nonconspiratorial markets. Prices, volume, and efficiency—all three move monotonically to the competitive equilibrium levels. This does not happen in the conspiracy markets. In each of the four experiments with conspiracy, with the possible exception of experiment III, at least one of these

[9] In still another study (Plott and Louis L. Wilde, forthcoming) sellers as a group (four sellers) knew they could collectively increase demand in the same sense that physicians, automobile mechanics, and other professionals can influence demand. The data give no support at all for collusion models.

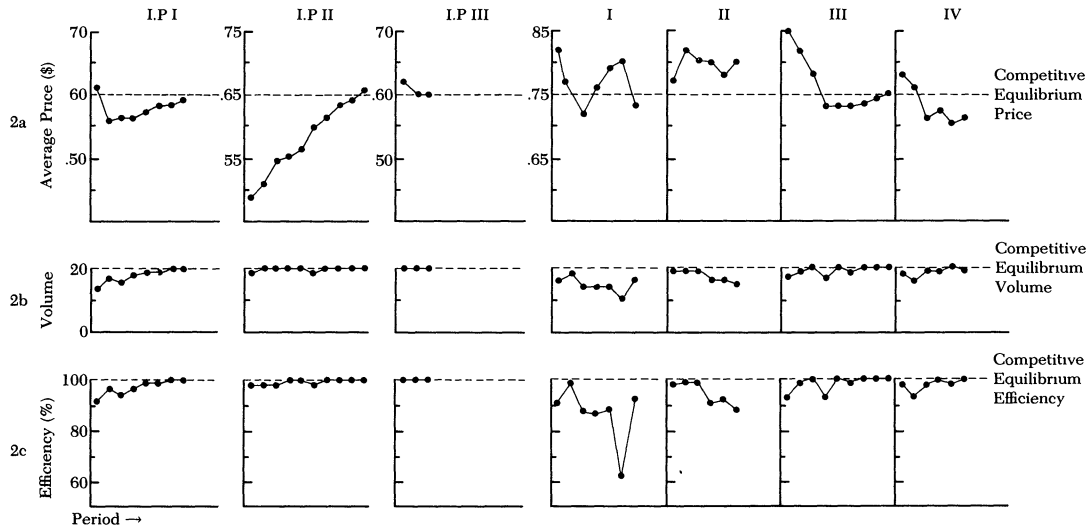


Figure 11. Average Price, Volume, and Efficiency Per Period

Source: Isaac and Plott (1981a, Figure 2, p. 10)

measures exhibits some erratic behavior in the sense of a "pronounced" movement away from competitive equilibrium. In this sense the conspiracy might be detectable from market data, but Experiment III indicates the difficulty. Notice in experiment III there is a strong tendency toward the competitive levels even though there is an active conspiracy.

Figure 12 will help explain what is happening. Shown there is the sequence of bids, offers, and contracts from experiment III. This experiment involved the dramatic reduction in prices in period 4 as a result of a successful buyer's conspiracy.

> Some general discussion began after period 3. Note that, unlike period 3, the buyers in period 4 did not rush to accept high seller offers. In period 3, five of the first six trades were offers between 83 cents and 88 cents. In period 4, no offers were accepted until they reached 73 cents. In period 5, the tenth bid was at 72 cents.
>
> Between periods 5 and 6 the [buyers][10] agreed to try to hold the price at 71 cents. In period 6, the first twenty-seven bids were all either at 70 cents or 71 cents, with several intervening offers at 72 cents ignored. The twenty-eighth bid broke the agreement, and there were ten immediate trades at 72 cents [Isaac and Plott, 1981a, p. 18].

Of particular interest in this context are the high offers in period 5. These are interpreted as signals by sellers as an attempt to get other sellers to hold out. Frequently, however, they are made by sellers who have already sold and now have only high cost units which they do not expect to sell. The cost of signaling to them is low. Nevertheless, the fact that the nonconspirators are not simply passive is obvious.

The difficulty these conspirators have in substantially affecting market conduct

[10] This corrects an error in the original paper (Isaac and Plott, 1981a) in which the word "sellers" was used instead of the correct word, "buyers."

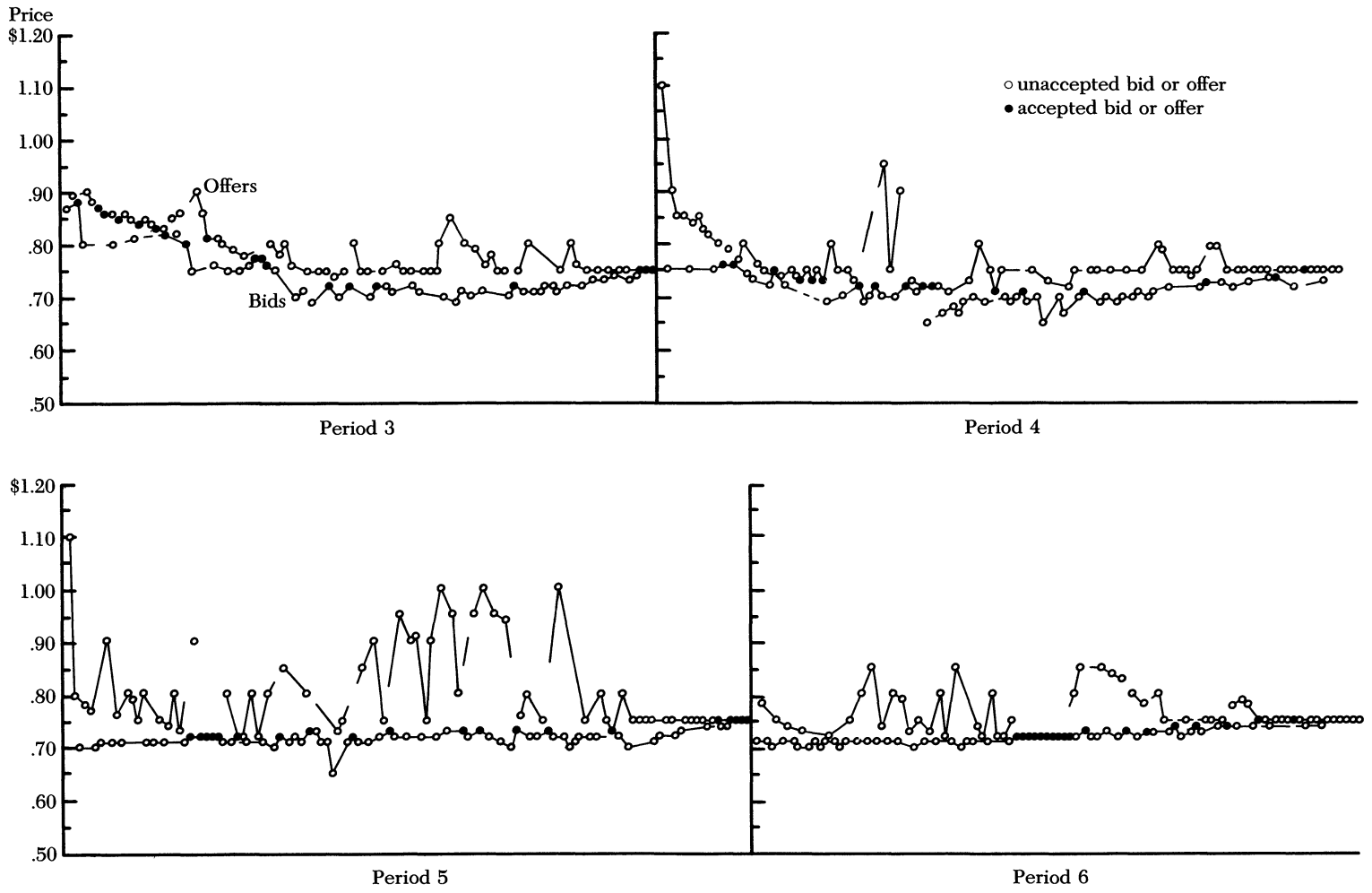


Figure 12. Experiment III—Periods 3, 4, 5, and 6, All Bids and Offers

Source: Isaac and Plott (1981a, Figure 11, p. 20).

seems to be related to the market institutional environment. As the Smith results reviewed above demonstrate, even a perfect conspiracy (monopoly) has difficulty in the double auction. When one adds this property of auction markets to the fact that oligopolists can have difficulty in achieving coordination even under the most favorable conditions, perhaps it is not surprising that the market structure in the Isaac and Plott experiments (four buyers and four sellers) would make successful conspiracy difficult.

B. *Privately Negotiated Prices*

The only nonconspiratorial oligopoly markets that have been studied experimentally in which prices are privately negotiated are those in the Grether and Plott (1981) study. In these markets demand was relatively inelastic. The supply condition was one of excess capacity at a constant cost over the relevant ranges. The market contained several similarly sized buyers, two large sellers, and two very small sellers. No entry was possible. All contracts were negotiated and executed privately by telephone.

In these markets each buyer and seller was located in a private office. Buyers had the phone numbers of sellers but not other buyers, and sellers had the phone numbers of buyers and not other sellers. Thus there was no possibility of conspiracy. In addition, phone calls were privately monitored through a master switchboard in a secretarial pool as a further control. Subjects were told that side payments or discussions of side payments in any form (e.g., physical threats) were prohibited and that if any were detected, the experiment would be terminated immediately.

In all other respects these markets were similar to those conducted under oral auction institutions. The time periods were longer (ten to fifteen minutes). As might be expected, the volume in a telephone market moves more slowly because of the time involved with dialing, negotiating, etc.

Results typical of these experiments are shown in Figure 6. Variance in price is high at first but begins to shrink over time. Prices, as can be seen, hang slightly above the competitive equilibrium. Nevertheless, the market behavior is still more closely approximated by the competitive equilibrium model than any other "standard" theory.

Conspiracy was allowed in a study by Selten (1970). Negotiations took place privately in booths. The four sellers each made supply quantity decisions before a period opened. The number of buyers varied between nine and twelve in the ten markets studied. Side payments, cartels, buyer and/or seller conversations, futures contracts, etc. were all permitted since one of the purposes was to see what practices emerged from the marketplace. Convergence to the competitive equilibrium can be read into many of the price patterns but abrupt movements away from equilibrium exist. On average the results are the competitive equilibrium.

C. *Posted Prices*

The posted-price institution has been used in almost all oligopoly experiments. The practice was (perhaps inadvertently) introduced by Hoggatt (1959) and by Fouraker and Siegel (1963). In the Fouraker and Siegel experiments each subject seller was given a profit table indicating profits as a function of own price and the competitor's price. Hoggatt used a mathematical demand function to determine revenues. In both cases the sellers, during a period, chose only a single price and the decision was irrevocable. Since a fixed revenue function or profit function was provided, the procedures implicitly assumed that

TABLE 2
FOURAKER AND SIEGEL PROFIT TABLE

Price Bid	Profit When I Have the Lower Price	Profit When I Am Tied for Low Price	Loss When I Have the Higher Price
$0.5	$.13	$.00	$ —
1.0	.35	.11	−.25
1.5	.53	.20	−.25
2.0	.67	.27	−.25
2.5	.77	.32	−.25
3.0	.83	.35	−.25
3.5	.85	.36	−.25
4.0	.83	.35	−.25
4.5	.77	.32	−.25
5.0	—	.27	−.25

Source: Murphy (1966, Item 1, p. 308).

buyers do not counterspeculate and therefore behave "passively" as under the posted-price institution. Thus, the results seem to be interpreted most appropriately within that classification.

Two different demand structures were used in these early experiments. In one series of experiments Fouraker and Siegel used a homogeneous product in the sense that a price above a competitor's resulted in a small loss. This reflects a primary interest of the experimenters in the Bertrand model of price determination as opposed to Cournot.[11] On the other hand, Hoggatt used individual demand functions for sellers which responded negatively if a competitor lowered prices, but volume for the high price seller did not adjust discontinuously to zero. Sauermann and Selten used a profit table based on quantity decisions. Both reflect an interest in the Cournot model. Fouraker and Siegel also conducted a series of experiments in which subjects each chose a quantity. Once the total quantity supplied was known, the experimenter would choose a price according to a predetermined demand schedule. All subjects then sold their chosen quantity at this price. The discussion below reviews the homogeneous case first.

In the Fouraker and Siegel "homogeneous commodity" design each competitor is given the profit table shown as Table 2 which is held constant for the duration of several periods. Use of a profit table implies that the market demand function is known with certainty (unlike experiments discussed above). Prices above a competitor's price result in no sales and a small loss. This property leads to the interpretation that the commodity is homogeneous. Cost conditions are such that zero profits were earned at the competitive equilibrium as shown. (In a feature added by James L. Murphy, 1966, price levels below this involved a loss for all agents.) The economic interpretation would be one of no rents, and one consequence of this lack of "producer surplus" is that prices must necessarily approach the competitive equilibrium from above. An important basic economic condition of

[11] The Bertrand model assumes all buyers will instantaneously shift to the lowest priced seller so unilateral price changes induce substantial volume shifts among competitors. The Cournot model assumes that all competitors necessarily charge the same price but a price cutter absorbs all new market volume induced by overall lower prices (Lester Telser, 1972, pp. 152–53).

these experiments was the symmetry of the payoff functions, thus implying something about similarity of costs (for the homogeneous product experiment the interpretation would be that all costs are constant at zero). Market structures were primarily duopolies but triopolies were also studied.

The primarily institutional variable aside from the posted price, involved the amount of knowledge available to agents. Under the Fouraker and Siegel *complete information,* the public information was that all agents knew all past price choices and profits of all other agents. In the *incomplete information* condition, the public information was that profits were unknown and an agent only knew at the end of a period whether his price was higher or lower than the competitor's.

If one uses as the market price the lowest price in the market (the price at which all trades takes place) then Fouraker and Siegel discovered a strong tendency for prices to converge toward the competitive equilibrium. In the case of incomplete information by the fourteenth period the competitive equilibrium price prevailed in eleven of seventeen markets and was at the neighboring price (the price nearest the competitive equilibrium) in six other cases. In the remaining experiment, the price was closer to the competitive equilibrium than to the joint maximum.

The complete information markets were characterized by a higher variance in behavior. Six of these markets were at the competitive equilibrium by the fourteenth period. Three more were at the neighboring price. Four were exactly midway between the competitive price and the joint maximum, and the other four were either at the joint maximum (two) or at the neighboring price (two). The additional information provided in this market setting tended to facilitate collusive behavior. Notice that the importance of the information is connected in some way to the market setting because public information (other than profits) in the oral auction facilitates no collusion at all.

Fouraker and Siegel also examined triopoly. All of the eleven markets operating under incomplete information converged by the fourteenth period to the competitive equilibrium. All but one of the ten markets operating under complete information also converged to the competitive equilibrium. Thus, in these experiments the number of sellers was an important variable when information was complete.

In a study by James L. Murphy (1966) a similar decay process was observed in duopolies operating under the incomplete information condition. In general, however, he found the decay process to be slower with prices tending to hang somewhat higher above the competitive equilibrium than in the Fouraker and Siegel experiments. By the fourteenth period, thirteen of seventeen duopoly markets were closer to the competitive equilibrium than to the joint maximum. The Murphy markets continued ten periods beyond the fourteenth period where the Fouraker and Siegel markets stopped. At the end of the twenty-fourth period, eleven of the seventeen markets were closer to the competitive equilibrium than the joint maximum and five were exactly at the joint maximum. The variance across periods within markets decreased. Thus markets either converged to the joint maximum or the competitive equilibrium, given more time, and the additional time enhanced the tendency to the former.

The Murphy experiments involved three changes from the Fouraker and Siegel experiments. More price choices were available. Prices below the competitive equilibrium were possible with losses resulting in prices in that range and of course the experimenter and subject pools differed. Murphy conducted only incomplete information markets with his own payoff charts. By comparing the rate of

cooperation with Fouraker and Siegel, he concluded that the threat of losses accounts for the higher rate. This conclusion is somewhat premature without a controlled experiment using the Fouraker and Siegel payoffs along with the Murphy payoff in the same subject pool and design. Rates of cooperation may well differ slightly from subject pool to subject pool and that might account for the differences with Fouraker and Siegel. Convergence to the joint maximum was not monotone. Instead, almost all of the duopolies experienced the decay to the competitive equilibrium at first and then, after several periods, prices began to drift upwards for those that ultimately converged to the joint maximum.

Presumably this "cooperative" phenomenon in duopolies operating under these conditions is facilitated by many trials and experience. The latter was explored extensively by Rolf Stoecker (1980) within the same parametric environment as Murphy but with complete information. Rather than many periods of a single market, Stoecker allowed individuals to obtain experience from different markets of ten periods each. Thirty-seven out of fifty duopoly markets managed substantial cooperation (at or near the joint maximum). None of the remainder exhibited the property of monotonic convergence to the competitive equilibrium. Jumps of price were common.

The Stoecker experiments provide new insights into the nature and possibility of tacit collusion. Nineteen of the thirty-seven markets which attained the coordinated equilibrium near the joint maximum did so with no signals or "learning." It occurred with the first price choice. Both competitors chose the joint maximum, and for the most part the systems stayed there. This behavior was prevalent among duopolists with previous experience. Thus, in this context, in which the harmony of interest could be clearly ascertained with no room for ambiguity or confusion, some duopolies needed no means of communicating intentions at all. Tacit collusion occurred immediately. For a subset (eighteen) of these fifty duopolies the joint maximum was not the individual maximum given equal prices. Of these, thirteen achieved stable equilibrium near the joint maximum and of the thirteen there were four which attained the equilibrium with the first move. Since these duopolists had twenty prices to choose from, it would be difficult to ascribe these coordinated actions to chance.

In Fouraker and Siegel, and in Stoecker both of the basic economic conditions of profit function symmetry (Stoecker studied two different types of asymmetry) and the market structure (two, three, and five agents) were examined. Symmetry results in high market prices. Presumably this is because coordination is easier—the actions of the other agents can be more clearly understood and there can be no disagreement over the joint strategies. If both are to charge the same price, a unique Pareto optimum exists. An increase in the number of firms almost always results in a convergence of price to levels near the competitive equilibrium. However, a slight upward bias relative to the competitive equilibrium even when the number of firms is "large," appears to be part of the general properties of the posted-price institution.

Fouraker and Siegel conducted another series of experiments which can be interpreted as a case of nonhomogeneous products.[12] In these markets, sellers each

[12] The Fouraker-Siegel subjects saw only profits expressed on tables as a function of the two participants' quantity choices. While Fouraker and Siegel generated these functions from a market demand with a homogeneous product and no costs, the functions themselves are consistent with other economic environments. In particular, one can generate these same profit functions from properly selected demand functions for nonhomogeneous products and properly selected cost functions. Furthermore, in the transformed environment, choice of quantity is

determined a quantity interpreted as the number of units to be offered for sale. After all decisions were collected by the experimenter, the quantities were announced and each subject could determine the profits from a prepared table. In the complete information case, competitors knew all previous quantity choices and profits of each other. In the incomplete information condition all previous quantity decisions of all participants were known to all, but each seller knew only his/her own profits. The fact that quantity decisions were known under the incomplete information condition induces an element of noncomparability between the homogeneous product case reviewed above in which price decisions were made and each competitor knew only who had the lowest price and not the price magnitude.

The results at the fourteenth period are summarized in Figure 13. Each market is categorized according to the model which most accurately predicts total market volume. As can be seen, the accuracy of the joint maximization or cartel model decreases with an increase in number of agents and also a reduction of information about the other agents' actions. Interestingly, the Cournot model as opposed to the competitive model seems to be most accurate in this "nonhomogeneous commodity" case. In the homogeneous commodity experiments the two models could not be given independent interpretations. Here they can and the Cournot model picks up much of the data. Whether this is the natural "upward bias" of the posted prices or an actual manifestation of the Nash equilibrium principle is still an open question.

The work of James W. Friedman (1963, 1969, 1970), Hoggatt (1959, 1967) and F. T. Dolbear, et al. (1968) has extended the posted-price research in several directions. In these markets, products are in a formal sense no longer homogeneous. Recall, in the Fouraker and Siegel setting, prices higher than a competitor's result in a loss to the competitor with the higher price. Presumably this reflects the idea that sellers with the highest price make no sales and, to the extent that costs are incurred, must suffer a loss. In the experiments to be discussed, the competitor with the highest price can still make some profit but not as much as would be the case if the price were equal to or below the other(s). As a result of this difference in market conditions the information conditions can be altered. Perfect information means that all profit functions and past price choices are known. Incomplete information means that all past prices (or quantities, as appropriate) are known but only an agent's own profit functions are known.

The findings are best represented in the recent book by Friedman and Hoggatt (1980) which describes the results of several oligopolistic markets under varying parametric information conditions and subject experience. Relative to other experiments these are exceptionally complicated because subjects made production and inventory decisions along with price decisions. Subjects gained experience as in Stoecker by participating in a series of different markets over a long period of time. In addition to more refined models of individual decisions, two basic market models are compared: the joint maximum model and the Cournot equilibrium. The competitive equilibria where price equals marginal cost are not examined. Of course, the Cournot equilibrium prices are above these prices.

Hoggatt and Friedman devote much effort to developing a model of individual behavior. The model developed, which has considerable support, assumes the in-

equivalent to choice of price. Therefore, the Fouraker and Siegel experiments can be interpreted as a case of price posting for a nonhomogeneous commodity.

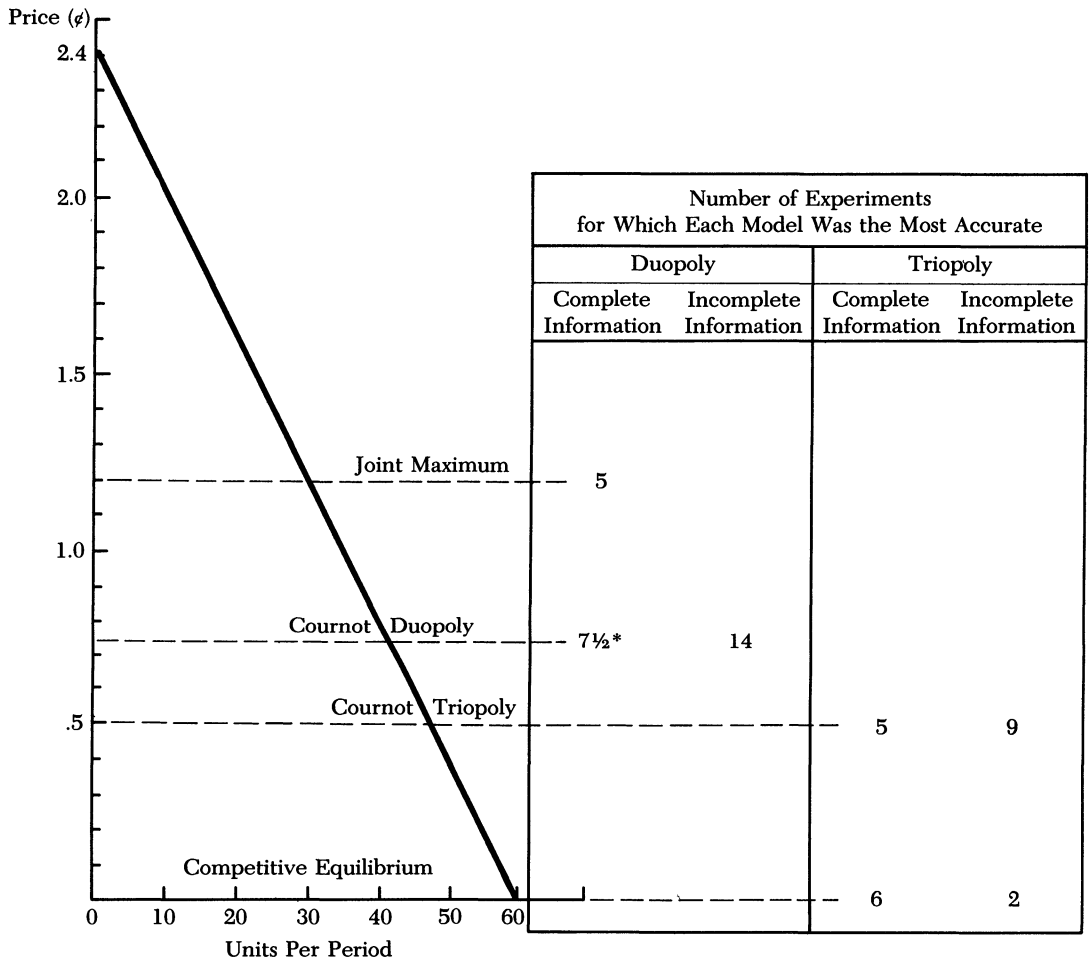


Figure 13. Fouraker and Siegel Parameters and Results

* The fraction indicates a tie between Cournot and competitive.

dividual develops estimates of the other agent's pricing decisions by an extrapolation of previous decisions. The individual then optimizes against that estimate. The resulting market equilibria are reinforcing in a statistical sense. Cournot behavior in this sense is a good first approximation of individual behavior when tacit collusion is absent.

If the markets are characterized by perfect information and symmetric profit functions, the joint maximum is a good predictor for markets with up to four sellers. For the market with six sellers, prices dropped substantially to the Cournot equilibrium or just above it. If the symmetry is dropped or if perfect information is dropped,[13] the number of sellers be-

[13] Information in Dolbear, et al. (1968) did not have a measurable effect. Subsequent experiments suggest that the payoffs used in this experiment were so small (five cents difference in profits between

comes a very important treatment variable in that an increase in the number destroys the accuracy of the joint maximum model. In the duopoly markets, significant (but less than perfect) cooperation occurs but, with an increase in the number of firms, it vanishes almost completely and the Cournot model is very accurate by comparison.

Friedman and Hoggatt conjecture what Stoecker convincingly demonstrates, that experience makes a difference. "New and inexperienced faces" can cause market prices to deteriorate.

Hoggatt, Friedman, and Shlomo Gill (1976), and Friedman and Hoggatt (1980) provide the only attempts to model the signaling phenomenon. In part, signals are viewed as attention getting devices. Most of the work is an attempt to identify a signal as something distinct buried in the masses of data of the ordinary searching and competing price decisions. Within the posted-price institution high or low prices have an immediate effect on profits, so as one might expect, signals occur rarely, relative to other decisions. Signals are identified as a type of "pulse" in which an abrupt change of behavior occurs for a brief period (a sudden large price increase or decrease) followed by a return to the original levels. Friedman and Hoggatt have attempted to develop models which will relate this activity to overall price changes and/or price levels. As of this writing they have a reasonable characterization of the phenomenon but feel it happens so infrequently in their data that the implications cannot be ascertained.

Thus, for the posted-price institution a pattern is emerging. The institution seems to foster higher prices in general. Furthermore, under appropriate basic economic conditions and market structures, it can foster tacit collusion in the sense that the joint maximizing model is an accurate predictor of pricing patterns.

If the market institution is the posted price as opposed to the oral double auction, and the market structure is duopoly, a completely different picture of conspiracy emerges. Friedman (1967, 1970) studied posted prices of duopolies with asymmetric payoff functions. Perfect information existed in the sense that each competitor knew all previous price choices and payoffs (up to a scalar transformation on occasion). Competitors were allowed to transmit two written messages before privately making a price decision. These messages were made in sequence with the same individual initiating contact for each of up to twenty-five periods (although most were from six to fourteen). In his data, collusive agreements were attained in over 75 percent of all decisions made, and of the collusive agreements, 75 percent were Pareto optimal relative to the pair (no side payments were allowed). The ability to make such agreements increases with experience. Once a collusive agreement has been attained and successfully implemented in choice behavior for one time, the probability of another successful agreement is .96.

An attempt to study collusion under the posted-price institution is also found in Selten and Claus C. Berg (1970). Side payments were possible with some risk that the payments would not be made. Each seller had the ability to stop the continuous time in these markets in order to make a price change. Other sellers were aware of price changes and could respond immediately. Collusive arrangements emerged, but not always.

Conspiracy does have implications for market performance. Perhaps this is no surprise to those who have observed in-

Cournot equilibrium and monopoly) that the influence of any variables would be hard to detect. Nevertheless, the data tend to be very close and just above the Cournot equilibrium and the qualitative influence of other variables is consistent with those of later studies.

dustry for years but these studies demonstrate the truth of the proposition for those who have not had the benefit of such observation or believe that the "competitive drive to defect" is so strong that collusion is impossible. Experiments illustrate that performance is strongly influenced by both market structure and the market institutional environment.

D. *Markets with Advance Notification and Price Protection*

The recent actions taken by the Federal Trade Commission[14] have drawn attention to the market institution in the antiknock compound industry.[15] Four industrial practices were in dispute. First, customers were assured of a thirty-day advance notice of price changes (increases). Secondly, prices were quoted in terms of delivered prices with the same price prevailing regardless of transportation costs. The last two were in contracts which typically included a "price protection" clause which guarantees (i) that the seller will sell to no one at a price less than the price quoted the buyer and (ii) the seller will meet any lower price in the market or release the buyer from the contract.

The market structure is characterized by two large sellers of equal size (approximately 35 percent of the market each) and two small sellers of about equal size. A long-run declining demand (due to a reduction in lead use in gasoline) and existing excess capacity discourages entry. Eight large buyers account for about 60 percent of the sales and many very small buyers account for the rest.

Grether and Plott (1981) have explored markets with these properties. Each agent was assigned an office. Sellers were able to post prices by means of a digital electronic display system such that price announcements were made known immediately to all market agents. Orders were placed through the telephone system. Price increases required advance notice and all transactions were made at advertised prices (the buyer protection clause which precludes all discounts). The market structure was as described above with the market demand and supply functions as shown in Figure 14.

The major conclusion of this study is that these practices and market structure cause prices to be above those that would otherwise exist if either variable were appropriately changed. Figure 14 gives the averages prices during each of seventeen trading periods. Market institutions were a simple telephone market during the first twelve periods. As can be seen, the prices begin to decay toward the competitive equilibrium. The four disputed practices were imposed beginning in period 13 and remained through period 15. As can be seen, prices jump immediately to near those which exist at the Cournot equilibrium. When the practices were removed (periods 16 and 17) prices immediately fell. These data are representative of the pattern of findings from ten experimental markets.

The theoretical explanation of this phenomenon has some support. Advance notice given sufficiently in advance of the deadline for advance notification provides a signal to other sellers. If the notice involves a price sufficiently far in the future, it induces no current business loss. Only a single price is involved, so the signal is uncomplicated with minimal dimensions over which disagreement can occur. Other sellers know that if they do not increase prices before the deadline, the original firm will rescind the proposed price increase. Thus other sellers do not have the option of "underselling" and acquiring a larger market share. The Nash

[14] The Federal Trade Commission complaint against Ethyl, DuPont, PPG and Nalco Chemical Company (Ethyl Corporation, et al. FTC Docket No. 9128. Complaint issued May 31, 1979).

[15] The product is added to gasoline by refiners to reduce knock and raise gasoline octane rating.

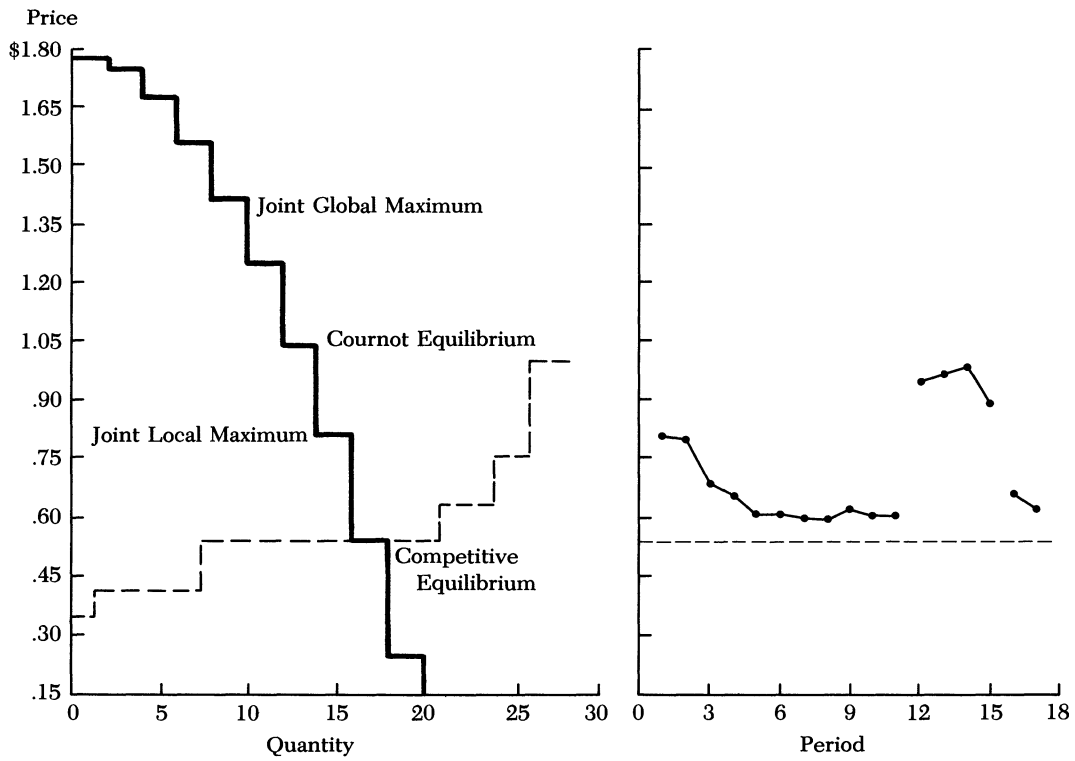


Figure 14. Parameters and Average Price Per Period

strategy for such firms is simply to match the proposed price if a uniform industry price at the higher level will increase the firm's profits and do nothing otherwise. On the downside, due to the homogeneous nature of the product, if not the buyer's protection, price cuts will be matched, so the incentive to cut prices depends upon the anticipated share of demand increase due to lower price levels. This model predicts that prices will certainly be at Cournot levels if not higher.

These institutions seem to have an effect on buyers similar to the posted-price institutions. Buyers do not anticipate discounts because the institutions prevent them. Furthermore, since any price concessions must be offered to all, buyers can see that price concessions can be costly to the seller and thus have less expectation of winning them. As a result, the buyers seem to have less "counterspeculation" than in, say, the telephone markets alone. Thus these institutions appear to remove one source of buyer pressure for reduced prices while at the same time easing the problem of price coordination for the seller and eliminating the advantages of price cuts.

V. *Defense of Experiments*

Many of the studies reviewed above were designed and executed to answer reasonably specific questions related primarily to basic science. Sometimes applied scientists dismiss the experimental results and methods as being irrelevant

and inapplicable. Needless to say, most questions cannot be answered by applying experimental methods. The theme of this section is on the art of posing questions which can.

The relevance of experimental methods rests on the proposition that laboratory markets are "real" markets in the sense that principles of economics apply there as well as elsewhere. Real people pursue real profits within the context of real rules. The simplicity of laboratory markets in comparison with naturally occurring markets must not be confused with questions about their reality as markets.[16]

If the reality of laboratory markets as markets is accepted, then the art of posing questions rests on an ability to make the study of simple special cases relevant to an understanding of the complex. General theories and models by definition apply to all special cases. Therefore, general theories and models should be expected to work in the special cases of laboratory markets. As models fail to capture what is observed in the special cases, they can be modified or rejected in light of experience. The relevance of experimental methods is thereby established.

Several different research strategies are apparent in the research reviewed in this paper but five will be identified here.

1. *Theory Rejection.* A model may be so poor at capturing observed behavior that it may be best to consider it no further or to use it even if no alternative model is available. The original experiments by Smith could be viewed as a potential basis for rejecting the ideas of demand and supply. If the model had not been at all accurate when applied to a simple market designed explicitly to give the model its "best chance," if, for example, the data were rectangularly distributed over the trading range in all periods, then it could be rejected as capturing none of the phenomena. However, the model worked extraordinarily well and as a result the original experiments were essentially ignored by the economics profession. Those who had a strong belief in principles of demand and supply said the results were "obvious." Critics of demand and supply dismissed the results saying that the markets were "rigged" so that demand and supply would work. When the approach is one of "model rejection," negative results instead of positive results are "interesting."

2. *Theory Competition.* In most cases competing models exist and existing data are not an adequate basis for rejecting one in favor of the other. The idea, then, is to create simple laboratory markets which are special cases of markets in which the models are generally applied. The experiments will, hopefully, indicate which is more accurate in the simple cases. While relative accuracy in a simple case does not prove that the model will continue to be relatively accurate when applied to the complex case, it does provide some experiences with the models. More importantly, it places the burden of proof squarely on those who continue to advocate the "losing" model to establish why the model they prefer would do relatively poorly in simple cases but perform relatively accurately in the complex. Presumably the arguments they advance in an attempt to establish this result can themselves be examined by application of additional theory and more complicated experiments.

3. *Model Robustness.* We have seen that changes in the market institutional environment can change market performance. These facts were discovered as experimenters inquired about the accuracy of the competitive model under alternative institutional regimes. These were checks on the robustness of the model under institutional perturbations. Similarly, some studies have checked the robustness

[16] See Plott (1979) and Smith (forthcoming) for a detailed discussion.

of the model under parametric perturbations such as number of competitors, demand elasticity, etc. Even though no formal theory (or any theory at all) exists about the influence of these factors, it is only natural to check. Then, once an important variable is found which was not anticipated by existing theory, the data from the experiments serve as a motivation for the development of extensions of the theory to cover the new facts. The influence of the posted price is a good example. No formal theory exists yet which completely explains the properties of this institution.

4. *Measurement.* When most scholars think of experiments, they have measurement in mind (e.g., What is the probability of tacit collusion? What is the speed of adjustment to equilibrium?). Laboratory experimental methods can be applied to these ends but none of the experiments above were predicated on the hypothesis that they were measuring numerical constants of nature. Questions of this type would seem to require elaborate sampling procedures and explicit definitions of the populations to which the measurement is to be applied. The studies above all involved hypotheses about *relative* behavior as opposed to numerical constants.

5. *Simulation.* Another popular preconception about the function of experiments is simulation. In circumstances in which a policy is going to be imposed on a social system, simulation objectives involve an attempt to recreate the situation on a smaller scale in order to provide decisionmakers with some experience with how the situation might evolve.

If there is no theory to indicate which variables are important, the complexity of the small situation must mirror the complexity of the large as closely as is possible. Furthermore, without theory to unify the observations, the experiment must be conducted enough times to assure the "statistical validity" of any asserted pattern in the results. Thus theory, even in the case of simulation, serves importantly to simplify the experimental process. The more that accepted theory can be invoked, the less the experimental process needs to "mirror" the natural analog. The tendency of scholars to reject experimental methods as irrelevant may be because they are fundamentally interested in simulation while being unaware of the role of theory on the one hand and being very aware of the complexities of the situation (and the impossibility of recreating it) on the other hand.

The arguments above are straightforward, but it is easy to be pulled off track. Sometimes scholars use the term "real world" to refer to nonlaboratory processes and the term "artificial market" or "simulated market" to refer to laboratory markets. Such language invites criticism by failing to acknowledge the argument above about laboratory markets being real markets. In addition, the language suggests that the primary test of relevance for laboratory market results is how closely the laboratory market approximates some naturally occurring market thus implying that the purpose is simulation. This test neglects all of the other modes of learning from experiments. The laboratory environments provide an arena within which the relative accuracy of competing general theories can be evaluated and the poorer models rejected. Recall that general theories and models of markets must apply to all special cases independently of how those special cases compare with some other complicated special case which could itself be the result of several accidents of history. In essence, a demand that laboratory experiments designed to test general theories should simulate some naturally occurring case in its full complexity denies the relevance of a study of special cases, and such a requirement would pose just as many problems for experimental methods in the physical

science as it would for experimental economics.

The problem of relevance can surface in many different forms. In the remaining paragraphs four of the most common sources of skepticism will be discussed.

The first argument is a claim that "real" businessmen do not behave as do the subjects in these experiments. Stated like this the argument is not a criticism of experimental methods, it is a hypothesis about behavior in different subject pools and is thus a call for more experiments (with businessmen subjects). Similarly, arguments that the monetary amounts involved were too little (or too much) are simply demands for more experiments. The fact of the matter is, however, that a variety of subjects and payment levels have been used. The Hong and Plott (1982) study, for example, used employed adults. To date, no subject pool differences which bear on the reliability of economic theory have been reported.

The next three arguments derive from the fact that naturally occurring phenomena are inherently more complex than are laboratory processes. The first argument is that the laboratory environment is *artificial.* Exactly why is not articulated, but with this argument the word is used many times and preferably loudly. It probably results from a gestalt view that there are so many important variables that they cannot be enumerated and that they interact in ways that are necessarily precluded in the laboratory.

This argument, notice, is not an argument against experimental methods in economics, it is an argument against experimental methods in general. The physical scientists must deal with it and so must the economists. Since the assertion cannot be falsified, the only answer lies in experimental work that has been helpful in generating successful models and points of view regarding more complex processes. As applied researchers find the data from experiments useful in shaping their own hypotheses and beliefs, this argument becomes less important.

The second argument is more specific in that it notes that naturally occurring processes do not occur in isolation. Industries are embedded in a larger social context. Businessmen have social relationships and friendships. They also know that their decisions while with one firm, may affect their possibilities for changing firms.

This argument suggests that behavior in very complex environments may follow different laws than those which govern behavior in relatively simple situations. This is an excellent reason for being careful in any attempt to extrapolate behavior from a laboratory to a complex industry. Notice, however, that it is not an argument against experimental methods. It is an argument for a particular type of experiment—one in which the complexity of the experimental environment is gradually increased to make its characteristics more nearly similar to those of a given industry. If complications destroy the applicability of models, it might be possible to identify the precise complications which cause the problem and adjust the model accordingly. In a sense this program of increasing complexity is exactly how experiments are proceeding.

The final criticism also relies on the complexity of naturally occurring processes. How is one to know if the elasticity of demand and costs used in an experiment or if the particular market institution are those of the industry? If the results of the laboratory experiments are to be applied, shouldn't these be "right"? The answer to these types of criticisms are still more experiments under varying parameters. With a wide range of parameters explored, the question collapses into a judgment about parameters and not the experimental methods.

All of these arguments should make one

cautious about extrapolating results generated from laboratory processes to naturally occurring processes. This type of extension must be dealt with artfully in the physical sciences as well as in economics. It is the most difficult task that any researcher faces. Experiments are simply an additional source of data and experience that one adds to other sources in making judgments about how the world works.

An easier task, involving a somewhat negative approach, places the burden of proof on those who advocate theories. General theories apply in special cases. They should therefore be expected to work in the simple laboratory environments and if they do not or if a competing theory works better, the burden of proof is on the advocate to tell us exactly why we should not judge him to be wrong. By adopting this point of view, researchers can use data from laboratory economics to reduce the size of the set of competing ideas.

VI. *Closing Remarks*

Experimental studies demonstrate clearly that market institutions and practices can influence market performance. Variables traditionally classified as aspects of market structure are also of demonstrable importance. Furthermore, rather standard mathematical models are able to capture much of what can be observed behaviorally.

Three models do well in predicting market prices and quantity: the competitive equilibrium, the Cournot model, and the monopoly (joint maximization) model. Experiments help define the conditions under which each of these alternative models apply. Some tendency exists for the error of a model when applied to data to be sensitive to structural and institutional variables (e.g., posted prices tend to be higher than prices under oral double auctions) but generally speaking, when a model applies, it does so with reasonable accuracy.

Interestingly enough, while experimental studies demonstrate that it is possible to model economic processes, they have also uncovered a problem in determining the conditions under which a model will be applicable. There is an interaction between variables which has not been fully explained. It is *not* the case that competitors are capable of collusive activity when merely recognizing a harmony of interests. It is also *not* the case that competitors *cannot* collude in the absence of direct communication and the enforcement of agreements. Competitors seem to be willing to collude (so the rivalistic hypotheses[17] advanced in the early experimental studies can be safely dropped) but some market structures and institutions make it easy while others make it almost impossible (in the sense that successful collusion has *never* been observed). Even a monopolist has difficulty within certain market institutions. Existing theory does not tell us exactly why this occurs, but the data suggest that one key is the behavior of the buyers. The data also suggest that market performance is very fragile (or "nonlinear") with respect to underlying structural and institutional variables and that "slight" changes (from four to two firms, or from price posting to some other institution) can switch a market from "competitive" to "collusive" or *vice versa.*

No doubt the ultimate usefulness of experimental work will be determined by demonstrations that experiments provide insights about what one finds upon close examination of industries. Prosecutors and regulators must choose which cases to prosecute and what reliefs to pursue, and frequently the choices must be based on very thin data and controversial economic

[17] This hypothesis maintained that competitors will attempt to maximize *relative* profits, thereby transforming the market into a zero sum game.

theories. The facts which might falsify the theory are often impossible to obtain without undertaking the long and expensive process of litigation. Experiments are an alternative, relatively inexpensive, and relatively quick source of data. How these data will be regarded by the courts is yet to be determined (John B. Kirkwood, 1981) but there seems to be no substantial difference between data from experimental markets and data from other types of experiments. Of course, this source of data has one more substantial advantage. The fact that experiments can always be rerun and the validity of claims checked, places severe veracity constraints upon those who might enter such data as evidence in a court proceeding.

APPENDIX

The instructions below are typical of those used in the experiments reviewed. Both posted bid market and oral double auction organizations are included. These instructions are read by the experimenter. The incentive forms (Figure 1) are also distributed. The forms are also reproduced on the blackboard and completed by the experimenter as directed by the instructions and the example in the instructions.

INSTRUCTIONS

General

This is an experiment in the economics of market decision making. Various research foundations have provided funds for this research. The instructions are simple and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you in cash.

In this experiment we are going to simulate a market in which some of you will be buyers and some of you will be sellers in a sequence of market days or trading periods. Attached to the instructions you will find a sheet, labeled Buyer or Seller, which describes the value to you of any decisions you might make. YOU ARE NOT TO REVEAL THIS INFORMATION TO ANYONE. It is your own private information.

Specific Instructions to Buyers

During each market period you are free to purchase from any seller or sellers as many units as you might want. For the first unit that you buy *during a trading period* you will receive the amount listed in row (1) marked *1st unit redemption value;* if you buy a second unit you will receive the additional amount listed in row (5) marked *2nd unit redemption value;* etc. The profits from each purchase (which are yours to keep) are computed by taking the difference between the redemption value and purchase price of the unit bought. *Under no conditions may you buy a unit for a price which exceeds the redemption value.* In addition to this profit you will receive a 5 cent commission for each purchase. That is,

[your earnings = (redemption value) − (purchase price) + 0.05 commission].

Suppose for example that you buy two units and that your redemption value for the first unit is \$200 and for the second unit is \$180. If you pay \$150 for your first unit and \$160 for the second unit, your earnings are:

\$ earnings from 1st = 200 − 150 + 0.05 = 50.05
\$ earnings from 2nd = 180 − 160 + 0.05 = 20.05
total \$ earnings = 50.05 + 20.05 = 70.10.

The blanks on the table will help you record your profits. The purchase price of the first unit you buy during the first period should be recorded on row (2) *at the time of purchase.* You should then record the profits on this purchase as directed on rows (3) and (4). At the end of the period record the total of profits and commissions on the last row (41) on the page. Subsequent periods should be recorded similarly.

Specific Instructions to Sellers

During each market period you are free to sell to any buyer or buyers as many units as you might want. The first unit that you sell *during a trading period* you obtain at a cost of the amount listed on the attached sheet in the row (2) marked *cost of 1st unit;* if you sell a second unit you will incur the cost listed in the row (6) marked *cost of 1st unit; etc.* The profits from each sale (which are yours to keep) are computed by taking the difference between the price at which you sold and the cost of the unit. *Under no conditions may you sell a unit at a price below the cost of the unit.* In addition to this profit you will receive a 5 cent commission for each sale. That is,

[your earnings = (sale price of unit) − (cost of unit) + 0.05 commission].

Your total profits and commissions for a trading period, which are yours to keep, are computed by adding up the profit and commissions on sales made during the trading period.

Suppose for example that your cost of the 1st unit is \$140 and your cost of the second unit is \$160. For illustrative purposes we will consider only a two-unit case. If you sell the first unit at \$200 and the second unit at \$190, your earnings are:

\$ earnings from 1st = 200 − 140 + 0.05 = 60.05
\$ earnings from 2nd = 190 − 160 + 0.05 = 30.05
total \$ earnings = 60.05 + 30.05 = 90.10.

The blanks on the table will help you record your profits. The sale price of the 1st unit you sell during the 1st period should be recorded on row (1) *at the time of sale.* You should then record the profits on this sale as directed on rows (3) and (4). At the end of the period record the total of profits and commissions on the last row (41) on the page. Subsequent periods should be recorded similarly.

Market Organization (Posted bid instructions)

The market for this commodity is organized as follows: we open the market for each trading day. Each buyer decides on a purchase price which he will write on one of the cards provided. The buyers will be given two minutes to submit their prices. The cards will be collected and the prices written on the blackboard. Sellers will then be free to make offers to sell whatever quantities they desire and to specify the buyer to whom they wish to sell. Offers will be made as follows: a seller will be chosen using random numbers, and will state the quantity he wishes to sell and the buyer to whom he wishes to sell. The buyer will then accept any part of the seller's offer by stating the quantity he wishes to buy. However, when a buyer posts a price, he must be prepared *to buy at least one unit.* If the first buyer will not purchase all units the seller wants to sell, the seller is free to choose a second buyer, and so on.

When the first seller has made all his contracts, another seller will be selected at random and he will make his desired purchases. The process will be continued until there are no offers to sell. This completes the trading day. We will reopen the market for a new trading day by having buyers submit new prices and the process will be repeated. Except for the offers and their acceptance you are not to speak to any other subject. You are free to make as much profit as you can.

Are there any questions?

Market Organization (Oral Double Auction)

The market for this commodity is organized as follows: we open the market for a trading period (a trading "day"). The period lasts for __ minutes. Any buyer (seller) is free at any time during the period, to raise his hand and make a verbal bid (offer) to buy (sell) one unit of the commodity at a specified price. The bid (offer) must be higher (lower) than the outstanding bid (offer) should one exist. Any seller (buyer) is free at any time to accept or not accept the bid (offer) of any buyer (seller). If a bid (offer) is accepted, a binding contract has been closed for a single unit and the buyer and seller will record the contract price to be included in their earnings. Any ties in bids or acceptances will be resolved by a random choice of buyer or seller. Except for the bids (offers) and their acceptance you are not to speak to any other subject. There are likely to be many bids and offers that are not accepted, but you are free to keep trying, and as a buyer or a seller you are free to make as much profit as you can.

Are there any questions?

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