Chapter 19

AN UPDATED REVIEW OF INDUSTRIAL ORGANIZATION: APPLICATIONS OF EXPERIMENTAL METHODS

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1. Introduction

From the very beginning laboratory experiments in economics were motivated by theories of industrial organization. The first published market experiments were those of Chamberlin (1948) who explored the behavioral characteristics of markets he described as being "purely" but not "perfectly" competitive. He thought that the principles of monopolistic competition would be more useful than the theory of competitive demand and supply in explaining the observed behavior. Hoggatt (1959) and Sauermann and Selten (1959) 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 Fouraker and Siegel (1963) which introduced several of the experimental techniques still used today. Smith's (1962) sensitivity to the organization of the floor of the stock exchanges 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-eight years.

The chapter is organized as follows. Section 2 outlines some of the step-by-step details of laboratory procedures. Sections 3–5 summarize experimental results; Sections 6 and 7 are methodological in nature. In Section 3 markets with several participants are analyzed and compared to the competitive model. Section 4 summarizes imperfect competition results. Section 5 deals with product quality. 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, which have been the traditional center of attention for industrial organization theorists. Consequently, on occasion it is easier to organize and summarize results according to market institutional variables as opposed to numbers, size, or other economic parameters.

Section 6 addresses the obvious question regarding the relevance of laboratory methods. Several common criticisms of experimental methods are outlined. The section defines 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. Critics who claim that laboratory markets are artificial have missed this fundamental point. They confuse simplicity with reality and fail to realize that they are grappling with a problem that accompanies experimental methods in general and not just in economics. Experiments in every branch of science are simple and special cases of the general and more complex phenomenon about which researchers are curious. The question that such critics wish to raise, and it is a question that must be answered in any experimental science, is whether or not anything is learned from the study of special cases. The answer to that more penetrating question depends upon the power and generality of our theories. Theory is the machine used to project us from the known special cases back to the unknown and more complex.

2. 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 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. The section is a brief outline of the procedures, methods, and measurements.

2.1. 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 and that otherwise neutral commodities receive value from the value of ultimate uses, i.e. derived demand. In an experimental market subjects

normally trade a commodity (e.g. a paper transaction) that has no intrinsic or use value. The commodity is given value by the experimental rules governing the redemption values of buyers and the terms on which sellers can acquire the units they wish to sell. Buyers make money by buying units 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.

The idea is deceptively simple. An important property is that the profits are real and sufficiently high to be comparable to the probable opportunity cost of the subject. 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 measures of the limit price schedules for the subjects. The first column of Figure 19.1 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 is entered in rows 3 and 4, respectively. As can be seen, these entries are made for each purchase during a period.

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 19.1 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 to suppliers are induced in a similar manner. The second column in Figure 19.1 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 as directed by row 3. 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, $\Delta C^i(x_i) = C^i(x_i) - C^i(x_i - 1)$, 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 19.1 you will notice a period indicator. Experimental markets are usually conducted over a series of periods of "trading days". The

REDEMPTION VALUES

INDIVIDUAL BUYER NUMBER _____

PERIOD _____

UNIT	ROW		VALUE
1	1	1st UNIT REDEMPTION VALUE	$2.10
	2	PURCHASE PRICE	
	3	PROFIT	
2	4	2nd UNIT REDEMPTION VALUE	$1.60
	5	PURCHASE PRICE	
	6	PROFIT	
3	7	3rd UNIT REDEMPTION VALUE	$1.10
	8	PURCHASE PRICE	
	9	PROFIT	
4	10	4th UNIT REDEMPTION VALUE	$ .85
	11	PURCHASE PRICE	
	12	PROFIT	
5	13	5th UNIT REDEMPTION VALUE	$ .35
	14	PURCHASE PRICE	
	15	PROFIT	
		TOTAL PERIOD EARNINGS	

COST

INDIVIDUAL SELLER NUMBER _____

PERIOD _____

UNIT	ROW		VALUE
1	1	SELLING PRICE	
	2	COST OF 1st UNIT	$ .15
	3	PROFIT	
2	4	SELLING PRICE	
	5	COST OF 2nd UNIT	$ .65
	6	PROFIT	
3	7	SELLING PRICE	
	8	COST OF 3rd UNIT	$ .90
	9	PROFIT	
4	10	SELLING PRICE	
	11	COST OF 4th UNIT	$1.15
	12	PROFIT	
5	13	SELLING PRICE	
	14	COST OF 5th UNIT	$1.65
	15	PROFIT	
		TOTAL PERIOD EARNINGS	

Figure 19.1. Redemption and cost incentive forms.

length of a period is normally from 5 to 15 minutes depending upon the volume of activity anticipated. Unless the commodity has some explicit properties of an asset which has a life over time [Forsythe, 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 redemption value and nothing about the redemption value of others.[1] The procedures and instructions are designed to keep this type of information private.

In early experiments agents were given a small "commission" ranging from 5 to 15 cents for each trade. It is known that individuals tend not to trade units unless there is some advantage for doing so. The function of the commission was thus to induce marginal trades by overcoming what seems to be a small transactions cost [Plott and Smith (1978)]. 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. This practice is reflected in Figure 19.2.

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 asks are orally tendered and publicly displayed, and only one outstanding (the last, the best, etc.) bid and ask is open at any time. Sellers (buyers) are free to accept an outstanding bid (ask) by a public, verbal indication. Thus, in the oral double auction, all bids, asks, and contracts are public information. Joyce (1983) demonstrates that the better information associated with the oral double auction as opposed to the Chamberlin process leads to a lower price variance, better convergence, and higher efficiencies.

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. As theory and experimental techniques improve,

[1]Only one market experiment has allowed such complete information and it did not converge as expected [Smith (1981)]. Bargaining experiments reported in Roth, Malauf and 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.

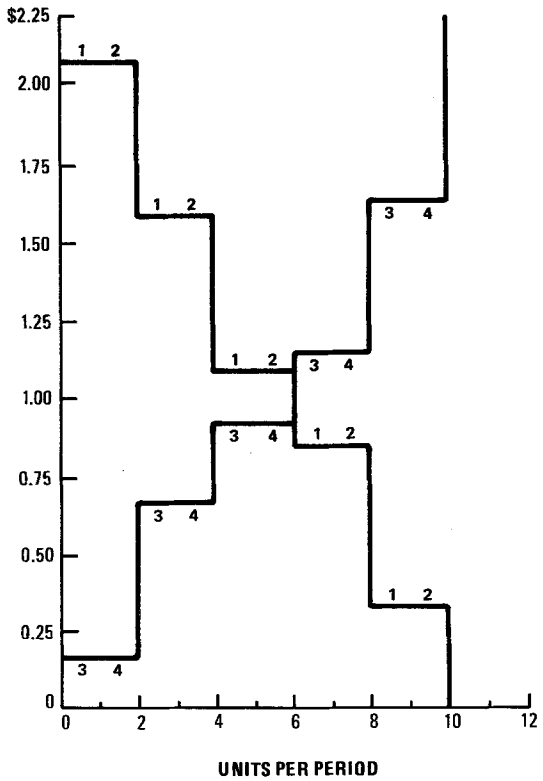


Figure 19.2. Aggregated limit values.

questions about the endogenous development of institutions and organization will be investigated.

Six prominent forms of market institutions have been studied in the experimental literature: (a) open outcry markets, (b) one-price mechanisms, (c) one-sided auctions, (d) posted-bid (offer) markets, (e) negotiated-price (telephone) markets, and (f) markets with "facilitating" devices.

Actually, the listing of only six 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 immediately "adjust" prices in light of the competition.

2.2. *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. 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, special electronic equipment designed for the experiment, and even citizens' band radios have been used. The most fully automated experiments are those using an interactive computer system.

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", "col-

[2]A possible example within the framework reviewed in this paper is explored in Cohen, 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 Hoffman and Plott (1983).

lusion", "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) – 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 example, marginal values are displayed in Figure 19.1 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 $8–10 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.

2.3. Performance measures

Price patterns, product quality, 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. Product quality is observable in the sense that different quality items can be identified as different commodities in multicommodity experiments.

Efficiency as introduced by Plott and Smith (1978) is more subtle than the other performance measures, 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. When uncertainty exists, the efficiency measure usually assumes no risk aversion and is thus based upon the maximum expected payment conditional on all the information that exists in the market.

In order to demonstrate how the measure of efficiency is related to ideas of consumers' plus producers' surplus, consider Figure 19.2. 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 19.1. The environment contains no random events. The suppliers are also identical and each has the marginal cost schedule in Figure 19.1. 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 19.2 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 19.2 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 when commissions are used. 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) trades are made, thereby capturing one aspect of efficiency. On the other hand, the commission seems to have no natural economic interpretation. Of course, in the example used here no commissions are used because the parameters are fixed to permit gains from marginal unit trades. Consequently, the problem does not arise.

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 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 surely trade and will 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 $0.85 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* "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 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.

3. Competitive market models

This section reviews markets that have several agents who participate without benefit of collusion or market institutions that might facilitate collusive behavior. The principal forms of market organization reviewed are the open outcry markets, one-price processes, one-sided auctions, negotiated prices, and posted prices.

The influences of market organization can be subtle. The competitive law of supply and demand captures much of the long run tendencies better than any competing model. Experimental studies attempt to identify the influences of differences in market mechanisms in terms of convergence speed, distribution of income, and market efficiency.

The discussion begins with open outcry markets and in particular the oral double auction mechanism because of its major role in the development of experimental methods. The oral double auction is the most efficient of known mechanisms. It is also, in a sense, the most complicated. Many of the other mechanisms can be understood as placing emphasis on some subset of the features of the oral double auction (ODA). That is, the ODA seems to be constructed from the other mechanisms that are reviewed in this section. Thus, the study of the other mechanisms can be interpreted as a study of the different "parts" of the ODA. These relationships will be described along with the description of the ODA.

3.1. Open outcry markets: The oral double auction

Open outcry markets characterize the trading floors of stock exchanges and commodity exchanges. To observers these floors appear chaotic and disorganized. Yet the experimental research uncovers a remarkable system of order. The oral double auction, which is a type of open outcry market, was first studied by Vernon Smith who observed the rather remarkable equilibrating power of the mechanism [Smith (1962)]. His amazement is reflected in a series of experiments designed to explore the possibility that the equilibration first observed was due to the shapes of the curves. He also explored ideas about the dynamics of the convergence process [Smith (1965)].

The oral double auction mechanism (for single-unit trades) works as follows. Each buyer is free at any time during a period to tender a bid to buy one unit at a specified price. Likewise, each seller is free to tender an ask.[4] If the bid or ask is the first after a contract, then the amounts are unrestricted. If the bid is not the

[4] The language here differs among experimenters. The word "offer" is frequently used in place of the word "ask".

first after a contract, then it must be strictly higher than the previous bid[5] and it automatically cancels the previous bid. Elements of the English auction or "ascending" auction are evident in the oral double auction as the competition among buyers forces the bids upward until a contract occurs. The rule governing sellers is symmetric with that for buyers. If an ask is not the first after a contract, then the ask must be strictly lower than the previous ask. As competition among sellers brings the prices down in an attempt to get a buyer to accept, a process similar to the descending price clock[6] of the Dutch auction can be seen. Any buyer (seller) is free to accept an ask (bid) at any time to form a binding contract for one unit at the specified ask (bid). The resulting interplay allows elements of a third type of market mechanism, negotiated prices, to be seen as a single buyer repeatedly increases the bid and a single seller repeatedly lowers the ask, each "bargaining" in hope that the other will accept. Elements of sealed bids are present to the extent that reservation prices privately held by buyers and sellers, the prices at which they are willing to accept a contract, are equivalent to the privately determined bids in sealed-bid mechanisms. Similarly the reservation prices could be related to the prices posted in posted-price markets.

The oral double auction can be conducted by "hand" but several computerized versions now exist.[7] The overwhelming result is that these markets converge to the competitive equilibrium even with very few traders. Figure 19.3 contains the results of four experiments. The price of every sale in the order in which it occurred is shown. Each period represents a market day with a given demand and supply. The competitive equilibrium is slightly above $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. This tendency is shown in all four experiments. If a change in parameters occurs, such as a shift in demand or supply, the prices converge to the new equilibrium after three or four periods.

As long as the industrial structure has a few buyers and sellers, these equilibrating 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 in the overall conclusion concerning equilibrium. The variations explored covered various cases of demand elasticity and nonlinearity. Except for some special examples to be covered later, shape seems irrelevant to the question of equilibrium.

[5]This improvement requirement is called the New York Rule.

[6]In the Dutch auction a price "clock" starts at a high price and decreases until the descent is stopped by a buyer. The buyer who stopped the clock purchases the item at the price on the clock.

[7]The original computerized experimental market was developed by A. Williams (1980) for PLATO. Programs now exist for HP (Tom Copeland, GSM, UCLA), and IBM pc net [Johnson, Lee and Plott (1988)].

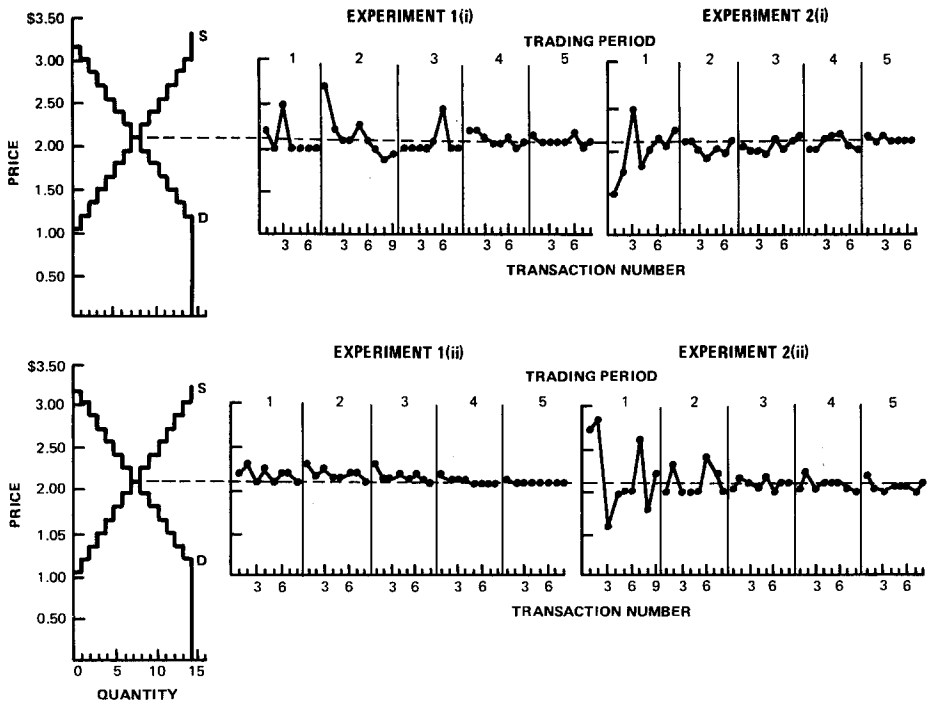


Figure 19.3. Oral double auction markets. *Source*: Smith (© 1976a, New York University, Chart 6, p. 53. Reprinted by permission of New York University Press).

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 Williams (1982a)]. 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 characterized by unanticipated demand or supply shifts, prices and profits can be affected by shape. Adjustment to a new equilibrium takes time, and profits or losses can certainly reflect disequilibrium trades. To date two studies have attempted to characterize the dynamic adjustment path [Smith (1965)], Daniels and Plott (1988)]. The conclusions from the Smith study are clouded by the fact that the choice of the estimation technique affects the conclusion regarding which dynamic adjustment theory Smith's data support [Nelson (1980)]. The Daniels and Plott study simply uses exponential adjustment as a maintained hypothesis

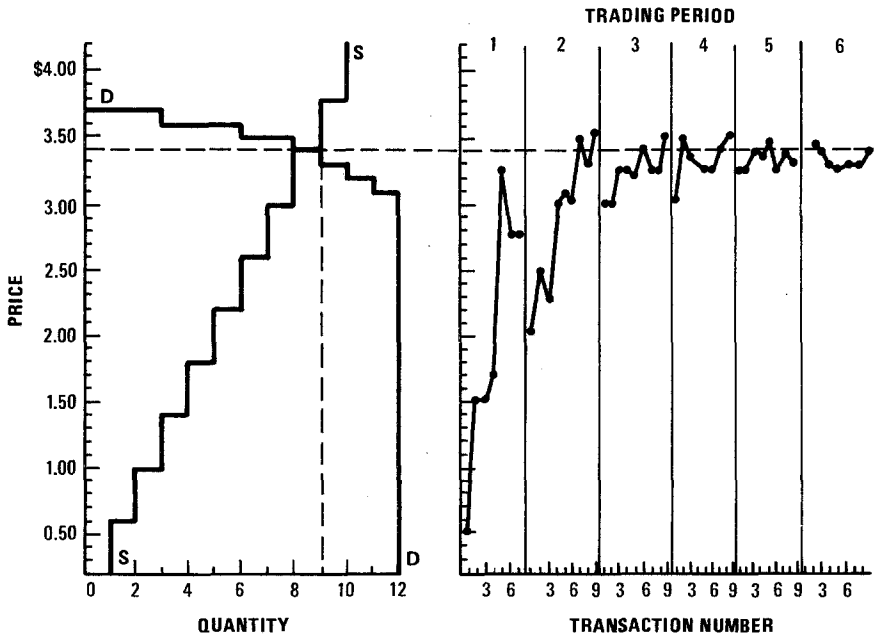


Figure 19.4. Oral double auction market. *Source*: Smith (© 1976a, New York University, Chart 3, p. 50. Reprinted by permission of New York University Press).

to demonstrate that markets with a constant percentage change in the competitive equilibrium equilibrate more slowly than stationary markets. 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 19.4 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.

Exactly why the convergence process occurs is unknown. Two theories have been advanced: Easley and Ledyard (1986) and Friedman (1984), but neither is a full explanation and neither has been systematically explored experimentally. Some general empirical properties are known. Computerized markets do not converge as rapidly as do those conducted orally. Expectations clearly play an important role in the convergence process. Both A.W. Williams (1987) and Daniels and Plott (1988) demonstrate that expectations in the oral double auction are near rational in the sense that the average of price forecasts are near the

actual average price. The relationship between the forecasts and price is not clear because the bids and asks clearly contain information [Plott and Sunder (1982), Daniels and Plott (1988)]. Some insight about the dynamics of market adjustments are also provided by studies of the effects of price controls. Isaac and Plott (1981b) discovered that *nonbinding* controls could affect the adjustment path. A price ceiling slightly above the equilibrium path will cause the market to converge from below. Removal of a binding or nonbinding price ceiling causes a discontinuous jump in prices. The phenomenon is documented and explored extensively by Smith and Williams (1981b). In a most interesting demonstration Coursey and Smith (1983) find that the properties of nonbinding price controls carry over to posted-price markets discussed later in this review. Insights about price dynamics are also revealed in experiments with rules regarding price changes in security markets [Coursey and Dyl (1986)], but generally speaking models that have attempted to capture the dynamics of the equilibration of the oral double auction have not successfully captured the data from these markets in which some sort of nonbinding control exists.

There exists one major exception to the convergence to the competitive equilibrium. Holt, Langan and Villamil (1986) studied markets with five buyers and five sellers. Figure 19.5 contains the results typical of the markets they created. As can be seen the market does not converge and the key to the reason is in the demand and supply parameters. The five buyers are about equally sized and the market demand is very steep at the competitive equilibrium quantity. Only a single unit of excess supply exists. Furthermore, this unit is held by a "relatively large" seller with inframarginal units who can benefit from withholding the unit and thereby increasing the price. The individual holds some market power in this theoretical sense. Four of the six markets they created failed to converge to the competitive equilibrium.

The results support the model used by Holt, Langan and Villamil that market power will cause the oral double auction to generate prices other than the competitive equilibrium. However, the conclusion remains open to an alternative explanation because the results are also consistent with the model of convergence developed by Easley and Ledyard (1986). With one unit excess supply the Easley and Ledyard model predicts that the competitive equilibrium need not occur. Because both of the models are consistent with the data, additional experiments are necessary to remove any ambiguity associated with the explanation offered by Holt and Villamil.

Several variations of the oral double auction have been studied. The rules developed above included a "New York improvement provision", which calls for any bid or ask to be an improvement over the previous bid or ask. Many early experiments did not utilize the improvement provision. Some markets have dropped the provision that only one bid and ask be outstanding [R. Miller and Plott (1985), Lynch, R. Miller, Plott and Porter (1986)]. Markets with a specialist's book have been studied [Smith and Williams (1982a)]. The mechanism has been

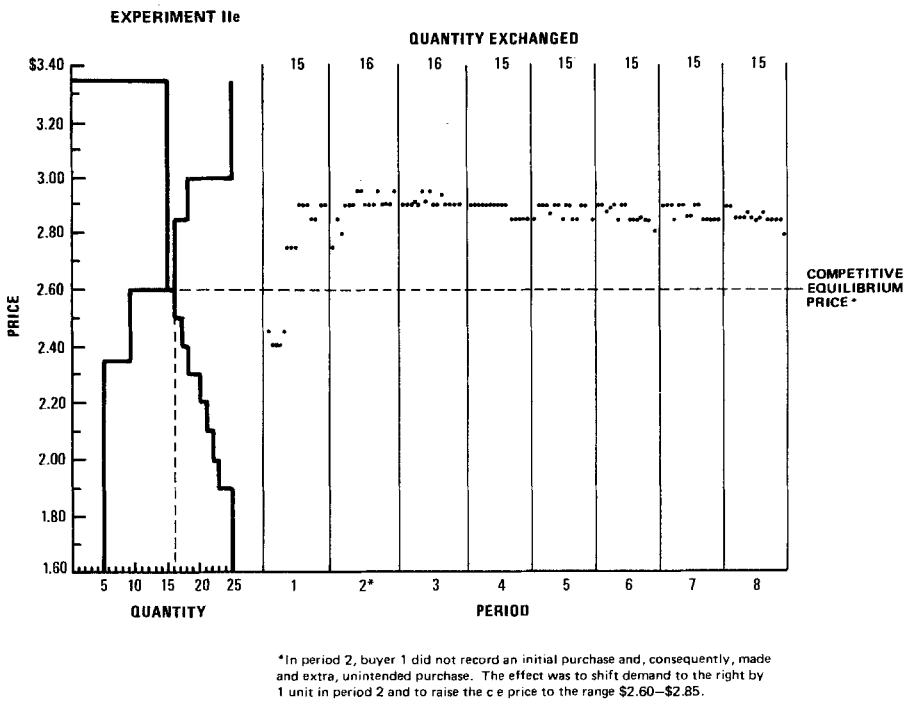


Figure 19.5. Oral double auction market. *Source*: Holt et al. (1986, p. 115).

generalized to accommodate multiple unit transactions [Plott and Gray (1988)]. While differences in these variations of the oral double auction mechanism have been observed, the overall convergence property has always been present.

It was once believed that one-sided oral auctions had special convergence properties. For example, it was thought that oral bid markets in which only bids and no asks could be tendered would converge from above [Plott and Smith (1978), Smith (1982), Plott (1982)]. Further research has demonstrated that the belief was formulated on an insufficient sample size [Walker and A.W. Williams (forthcoming)] and that the direction of convergence from one-sided oral auctions is no different from the double oral auctions.

3.2. One-price mechanisms

Trading in the oral double auction takes place at many different prices. With time and repetition the variance of prices decreases but the existence of trades at

"disequilibrium" prices is a fundamental property of the process. By contrast one-price mechanisms attempt to find a single price at which the market "clears" and all trading takes place at that price. If the mechanism finds the competitive equilibrium price and facilitates all trades there, then the process would be 100 percent efficient. And if the competitive equilibrium price was obtained sufficiently quickly, the mechanism would outperform the oral double auction.

Two one-price mechanisms have been studied; a tâtonnement mechanism and a sealed bid-offer mechanism. The tâtonnement mechanism operated as follows [Joyce (1984)]. An auctioneer announced an arbitrary price. Buyers would each indicate on a card the amount they were willing to purchase at that price and the sellers would each hold up a card indicating the quantity they wished to sell. Subjects were not informed of the excess demand or supply at a price. They only knew if the price changed. Price changed according to the rule $\Delta P = 5¢$ (revealed excess demand). If excess demand was small or flipped from positive to negative, the price changes became small with the exact amount "judiciously chosen" by the auctioneer. When the market cleared exactly the process stopped. Clearly, this stopping rule is important for the manipulability and observed efficiency of the mechanism. The exact rules for price changes were not told to the subjects so the latitude for manipulability was narrow.

Six markets were conducted with ten buyers and ten sellers who were able to trade one unit each. Trading in all markets was near the competitive equilibrium but prices did not settle down at the competitive equilibrium price and quantity. Only eighteen periods of a total of fifty-three periods were at the competitive equilibrium price and thirteen of the eighteen were at the competitive equilibrium volume. The marginal units tended to not trade. Consequently, efficiency of this mechanism might prove to be below that of the oral double auction in which marginal units do tend to trade,[8] but comparison experiments with the oral double auction were not conducted. Joyce did experiment with segregated buyers and sellers in a manner that placed each group in a separate room and made revealed demand public to buyers and revealed supply public to sellers. Some systematic underevaluation of quantities (relative to the competitive response) appears to be due to the segregation and related information changes. The important lesson seems to be that strategic behavior can be detected within a tâtonnement mechanism so it need not perform as competitive theory suggests.

Sealed bid-offer mechanisms were studied by Smith et al. (1982). Buyers submitted sealed bids and sellers submitted sealed asks. The bids were arranged in a market demand function and the asks were arranged in a supply function. Price was determined by the intersection of demand and supply. If the price so

[8]The efficiency numbers that Joyce reports are a little misleading. Commissions are paid by Joyce but are not included in the efficiency measure. Thus the numbers he reports do not reflect untraded marginal units.

determined was not unique, then the market price was the midpoint of the set of prices such that excess demand was zero.

Two different sealed bid-offer mechanisms were studied. In the first, termed PQ, buyers (sellers) could submit only a single price and maximum quantity they wished to purchase (sell). That is, only rectangular individual demand (supply) functions could be submitted. In the second mechanism, called $P(Q)$, there were no restrictions on the individual demand and supply functions that can be submitted. A separate price could be bid (ask) for each unit.

The two basic mechanisms were studied with and without the existence of a voting procedure. When the voting procedure was in place, these who had positive purchases or sales at the market-determined price were allowed to vote on whether or not the process would iterate thereby letting agents submit new demand and supply functions. Thus, in reality, four one-price processes were studied: PQ, $P(Q)$, and when votes were added, these mechanisms became two new mechanisms, PQv and $P(Q)v$.

The "best" mechanisms in terms of efficiency were the oral double auction and $P(Q)$. The next ordered by efficiency was $P(Q)$. The worst were PQ and PQv. Both of these latter suffered because of phenomena that Smith interprets as the strategic behavior reminiscent of monopoly vs. monopsony, which appears to be encouraged by the mechanism.

3.3. Auction markets (sale of a fixed supply)

The study of auctions is central to the study of industrial organization because auction processes seem to be the building blocks from which more complicated markets are constructed. All markets have features that are formalized in auctions. In a sense auctions embody the pure form of institutional arrangements.

A natural question turns on the degree to which the broadest of tools, the law of supply and demand, can be relied upon to predict the results of auctions. The demand and supply model is easy to apply. A fixed supply is auctioned so the supply function is vertical. The demand curve is dictated by the limit prices. A second natural question to ask is whether or not the market behavior is influenced by the type of auction. Of course a third question is what deeper principles dictate the answer to the first two questions. Those three questions are at the heart of the research.

Almost everyone is familiar with the English auction. According to the English auction rules (sometimes called a progressive auction) each unit is sold to the highest bidder. Each unit is auctioned separately with prices bid up in increments determined by the bidders themselves perhaps with the aid of an auctioneer. The unit is sold when the ascent stops or is stationary for a predetermined length of time.

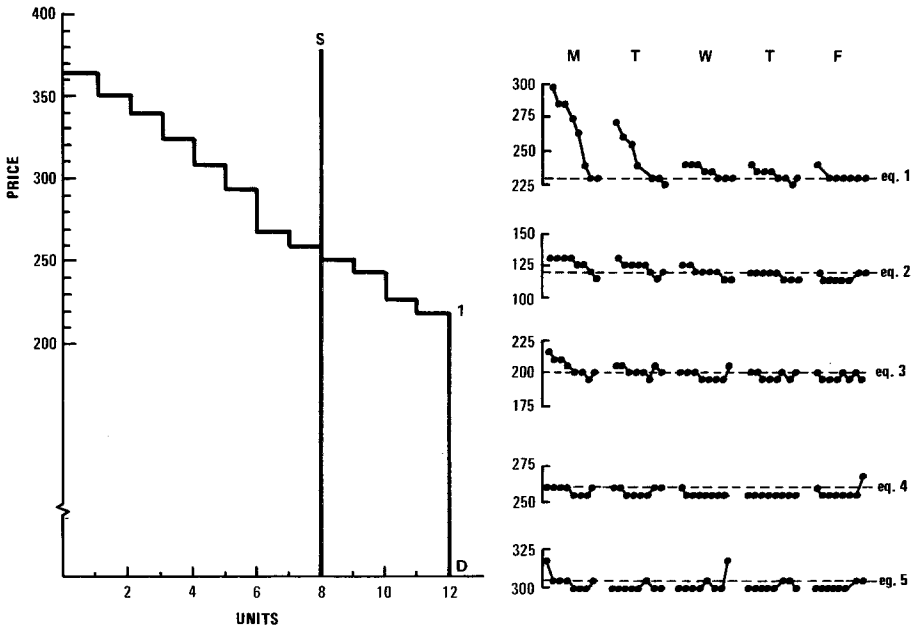


Figure 19.6. *Source*: P. Burns (1985, Fig. 1, p. 280, and Fig. B.1C., p. 297).

The convergence property of a multiple unit English auction under stable demand and supply conditions has been demonstrated[9] by Burns (1985). Figure 19.6 contains an example market from the series she reports. Each period a supply of eight units was sold. The demand curve was induced by the techniques described above. It was stationary as shown in the figure for five periods. Each trader knew only his/her own redemption values. As can be seen the first trades tend to be above equilibrium as high valued buyers compete with one another for the first units. With repetition the prices tend to equilibrate with low variances near the competitive equilibrium. Does the English auction always come into the equilibrium from above? Is the direction of convergence influenced by the shape of the curve? The answers to these questions are currently unknown.

Sealed-bid auctions are also common. The first sealed-bid experiments with many bidders were conducted by Smith (1967). The possible convergence to the competitive equilibrium was not the question posed by the early Smith experiments. Instead, his experiments were motivated by a controversy about the

[9]In an earlier work the English auction was studied by Frahm and Schrader (1969) who compared the English with a Dutch auction.

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 prices equal to the bids. 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.

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

The question about the revenue-generating capacities of the two auctions was pursued further by G.J. Miller and Plott (1985) who also studied the behavior of repeated auctions under conditions of stationary demand and supply. This allowed the equilibrating properties to be observed and checked to see if the law of supply and demand applied. In the Miller and Plott study the personal value of the object was known with certainty but the values of other bidders was unknown. Bidders could purchase more than one unit. Individual demands were rotated each period in a manner which preserved aggregate demand but changed each individual demand.

The principal result of the 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. Convergence is near the competitive equilibrium, and after convergence takes place, these two types of auction generate about the same revenue. A conjecture about the Smith–Belovicz conjecture also emerges from the study. In order to increase excess demand, Smith and Belovicz increased the number of demanders. If this increase in numbers also resulted in an increase in the slope, as from a population in which risk aversion was normally distributed could do, the latter and not the excess demand would account for differential revenues observed by Smith and Belovicz.

Figure 19.7, taken from G.J. Miller and Plott (1985), 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

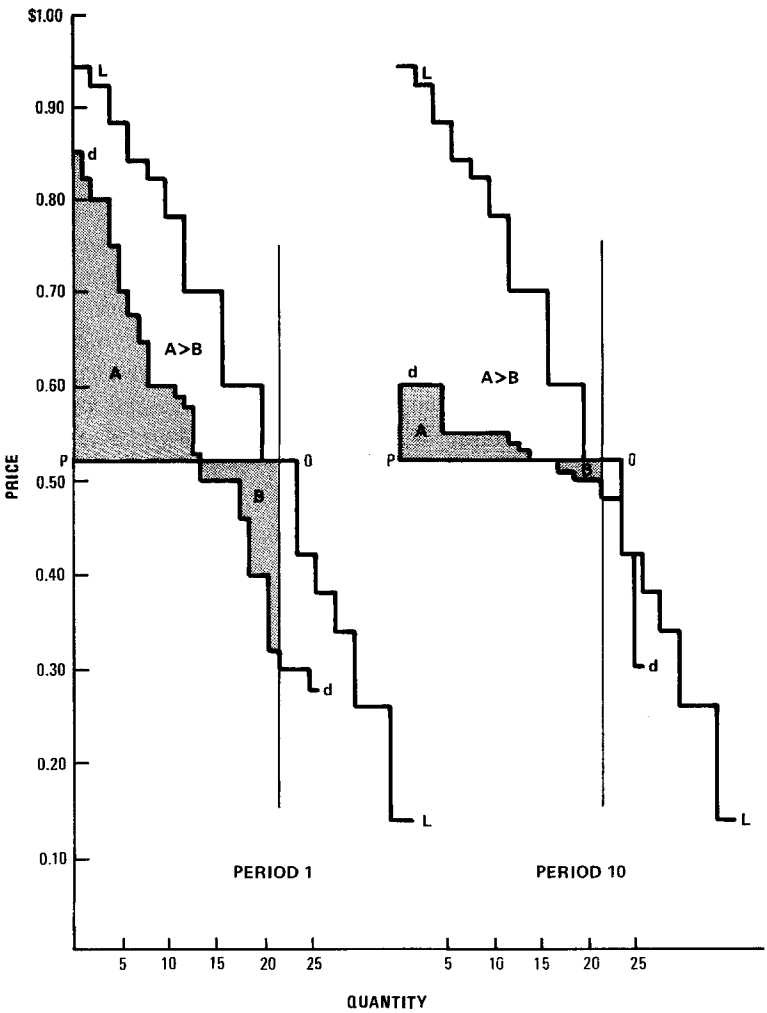


Figure 19.7. Demand and revealed demand in a discriminative auction. *Source*: G. Miller and Plott (1985, pp. 172, 173) and Plott (1982, p. 1506).

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.

Exactly why these auctions converge to the competitive equilibrium (or Nash equilibrium) is not fully understood. Intuitive explanations are not hard to generate but an explanation based upon first principles is something else. In fact, there exists no formal model of the convergence process shown in the two figures.

Formal models of bidding have been developed in a different environment. Assume that only one unit per period is sold. Assume further that individual valuations are drawn at random each period from a distribution that is public information. Thus, market demand as well as individual demands are not stationary from period to period. Modern auction theories based on such environments were tested by Coppinger, Smith and Titus (1980). The market institutions they examined there are the English auction, the Dutch auction,[10] first-price sealed-bid auction, and the second-price sealed-bid auction. Theoretically (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. Revenue from the Dutch auction and first-price auction should exceed that of the English auction and the second-price auction. Many experiments with these auctions 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. The models capture some of the data but paradoxes and contradictions exist.

The theory was explored even further in Cox, Roberson and Smith (1982) which investigates the general reliability of the Nash equilibrium hypothesis. For purposes of exposition we will report only on the single-unit case in which individual values v_i are independently drawn from a constant density on $[0, 1]$. By expressing bids as a fraction of the largest possible value the results generalize to any interval. Each agent knows his own value before bidding but not the value of others. The above facts are public knowledge and can be controlled for experimental purposes; that is, auctions can actually be created that objectively have the requisite properties.

The auction theory literature suggests that the system will behave *as if* the following are true.

(a) Agents choose in accord with the expected utility hypothesis. In order to obtain a model that can be solved we will assume each player has a utility function of wealth $U_i(y) = y^{r_i}$, where r is distributed across the population by a publicly known probability distribution ϕ on $[0, 1]$. The constant r is a risk aversion factor. This assumption will be treated as a maintained hypothesis for purposes of analyzing the data and testing the theory.

(b) At the time of choice each agent, i, knows (v_i, r_i), his own value and risk parameter, but knows only the probability distribution from which those of others were drawn.

(c) Each individual follows Bayes's law in forming expectations.

(d) Each individual will choose a Nash equilibrium bidding function.

(e) There are N agents.

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

Table 19.1
Theoretical predictions and means and variances pooled over n markets

		First		Second	
N	Statistics	Observed price	Risk neutral ($r = 1$) theoretical	Observed price	Theoretical
3	Mean	2.44 ($n = 70$)	2.5	1.97	2.5
	Variance	0.589	0.384	0.759	0.96
4	Mean	5.64 ($n = 60$)	4.9		
	Variance	1.80	0.96		
5	Mean	9.14 ($n = 60$)	8.1		
	Variance	1.37	1.83		
6	Mean	13.22 ($n = 60$)	12.1	11.21	12.1
	Variance	4.31	3.0	8.20	6.4
9	Mean	31.02 ($n = 30$)	28.9	27.02	28.9
	Variance	4.91	8.38	18.66	18.85

Source: Cox, Roberson and Smith (1982).

Under all of the above assumptions the symmetric Nash equilibrium bidding functions are:

$$b_i = \begin{cases} v_i, & \text{for all } i \text{ if the second-price auction is used,} \\ \dfrac{(N-1)v_i}{N-1+r_i}, & \text{for all } i \text{ if the first-price auction is used.} \end{cases}$$

The comparative institutional prediction is that the expected price under the first-price auction is greater than the expected price under the second-price auction. Table 19.1 reproduces the results of some of the Smith et al. experiments. The range of the support function $[0, \overline{V}]$ was varied with N to keep expected profits, as calculated by the model, the same as N increased. Notice first that the model is very accurate when applied to the second-price auction for $N > 3$. For example, if $N = 6$ the model predicts a mean price of 12.1 and the actual price averaged 11.21. The predicted variances are also close to those observed. As predicted by the model, people tend to bid their value when they participate in the second-price auction. Secondly, notice that the prediction about the *market* treatment variable is also correct. The average price for the second-price auctions is below the average price of the first-price auctions for every value of N. The first-price auction generates more revenue as predicted.

The risk neutral model ($r = 1$) tends to develop inaccuracies when applied to the magnitude of first-price auction bids. Of course, the risk neutrality parameter was not controlled in these experiments. In any case, prices in the first-price auction are higher than those predicted by the model if we assume $r = 1$. If the data are tested against the risk averse model, which predicts that observed prices

will be above the risk neutral prediction, for every value of N the model cannot be rejected for $N > 3$. Cox, Smith and Walker (1985) report on examinations of individual bidding behavior that test more directly the existence of the constant relative risk aversion utility used in the model. Their data continues to support the model but some rather sharp contradictions were observed when they attempted to apply incentive methods that might control for risk aversion [Berg et al. (1986)].

The support for the Nash equilibrium-based models has continued [Cox, Smith and Walker (1984)] as research has expanded to a study of the multiple units case although the model has encountered difficulties for some values of N. For the single-unit case, however, the full Nash equilibrium model with all of its implicit and explicit rationality assumptions is the most accurate model that exists. To the extent that the model places restrictions on data it is consistent with the facts in an absolute sense.

Recently the study of experimental sealed-bid auctions has been extended to the more general class of common-value auctions in which a "winner's curse" can occur [Kagel and Levin (1986)]. The winner's curse involves a type of systematic overbidding for an item with an uncertain value, thereby causing the winners to lose money on average. A prominent theory is that the phenomenon exists because of a systematic and special type of judgment failure of the bidders as opposed to a more general failure of rationality or a more general failure of the Nash equilibrium model. The research centers around two fundamental questions: (a) Can a winner's curse be observed, and (b) does it occur because of the particular theoretical reasons? The answers to both questions are the same – yes.

The experimental auctions used in the Kagel and Levin study each consisted of the sale of a single item to the highest bidder. The redemption value of the item was the same, unknown value to all bidders. The value of the item, V, was determined prior to the auction by a draw from a uniform distribution over the internal $[\underline{V}, \bar{V}]$. Typically the internal was [\$15, \$100] or [\$25, \$225]. Once the value, V, of the item was determined, each agent was given a private signal x_i about the value. The variables, x_i, were drawn from a distribution uniform on the interval $[V - \varepsilon, V + \varepsilon]$, e.g. [$V$ − \$12, V + \$12].

Now the expected value of the item given a signal is

$$E(V|x_i) = x_i. \tag{1}$$

However, the relevant expected value for purposes of bidding is the expected value given that the agent won the item, which intuition correctly suggests, is the expected value given that the agent's private signal is the highest. Because an order statistic is involved, the formula becomes:

$$E(V|x_i = \text{highest}) = x_i - \varepsilon\frac{(N-1)}{(N+1)}. \tag{2}$$

The potential irrationality can now be seen. If competitors use the second, correct formula in computing a bid function, the risk neutral Nash equilibrium bid function is

$$b(x_i) = x_i - \varepsilon + y \quad \text{(RNNE)}, \tag{3}$$

where $y = [2\varepsilon/N + 1]\exp[-(N/2\varepsilon)(x_i - \bar{V} - \varepsilon)]$. Suppose agents use the expected value neglecting the order statistic property. Then the bid function becomes the bounded rational function:

$$b(x_i) = x_i - (2\varepsilon/N) + Y/N \quad \text{(BR)}. \tag{4}$$

If $N > 3$ the bounded rational function (BR), equation (4), produces a winner's curse. That is, $b(x_i) > E(V|x_i = \text{highest})$. So the function (BR) of equation (4) becomes a model to be compared with (RNNE) of equation (3).

The experimental data provide no support for the winner's curse in groups of size 3 and 4. The RNNE model did better than the zero (to negative) profit prediction of winner's curse model. The bids were somewhat higher than predicted by the model with profits averaging 0.68 of predicted profits. In groups of size 6 or 7 the picture differs. Negative expected profits occurred regularly. Furthermore, the mechanism by which the losses occurred was substantially as outlined by the bounded rationality theory. The agents with the highest signals tended to win the auctions. The bids tendered by the winners were closer to the BR model than to the RNNE model.

The winner's curse experiments are particularly interesting. The data continue to generate support for Nash equilibrium behavior. However, the Nash equilibrium operative in these markets is derived from individual decision rules that contain a systematic statistical error on the part of agents. Agents behave strategically but they do not adjust for the order statistic property of the winning bid and they do not behave as if other agents will make the same error. The errors appear to be transitory in the sense that trial and error with the accompanying losses appears to discipline participants into "rational" behavior, but the data suggests that the learning is situation specific. That is interpreted to mean that the reasons for the error, as captured by the order statistic property is not automatically incorporated into the cognitive aspects of the decision and is therefore not carried over to unfamiliar bidding situations. In other words, the learning is not rational in a cognitive sense.

Experimental auction research has not been restricted to basic science. Grether, Isaac and Plott (1981, forthcoming) used the results of experimental auction markets as the tool for exploring proposed reform of methods of determining air-carrier access to the four major airports. At the time, 1979, airport access was determined by committees of carriers certificated to operate at the airport. These

committees operated under unanimity. The Grether, Isaac and Plott report was based on a direct study of these committees; a study of experiments with committees operating under the same rules; and a study of experiments with auction processes that were designed to do the same allocation job as the committees.

The report concluded that the committees should be replaced by one-price auctions with an aftermarket. It also recommended either lotteries with an aftermarket or grandfathered rights with an aftermarket as alternatives. After several years of politics an alternative process involving grandfathered rights to land and markets for these rights was adopted.[11] The landing right problem is especially interesting because of the complementarities among items to be sold at different auctions. A carrier might not want the right to take off at O'Hare unless it had the right to land at Washington National. Yet the rights were to be sold at different auctions. The obvious coordination problem has been addressed by a new type of computer assisted auction, created by Rassenti, Smith and Bulfin (1982) that ties these markets together.

The exploration of sealed-bid institutions is initiated along a different dimension by Palfrey (1983, 1985). 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.

3.4. Negotiated prices

A large and diverse literature addresses two-person bargaining [Roth (1987)]. One approach to the analysis of markets with negotiated prices would be to build principles of market behavior from models of two person interactions. Currently that is not possible. An alternative approach is to study the market aggregates without a full understanding of the activities at the levels of pairs of bargainers. Studies that adopt this alternative approach are reviewed here.

Market mechanisms in which price negotiations take place have two prominent features that have been explored. The first is the fact that the price setting process is negotiated, which appears to involve much more complicated strategy spaces than mechanisms like the oral double auction. If negotiation is face to face or involves verbal communication, the potential sources of information, signals, etc. are so numerous that no real attempt exists to completely characterize the

[11] Correspondence between Charles Plott and Chris deMuth in *Aviation Daily*, Washington, D.C., 25 July, 1983, back of pages 124 and 127.

mechanism. The second feature is the potential private nature of negotiations. Negotiation strategies, positive final contract prices, opportunities, etc. may be known only to the contracting parties so shopping and searching for better deals may be costly in terms of time and forgone opportunities.

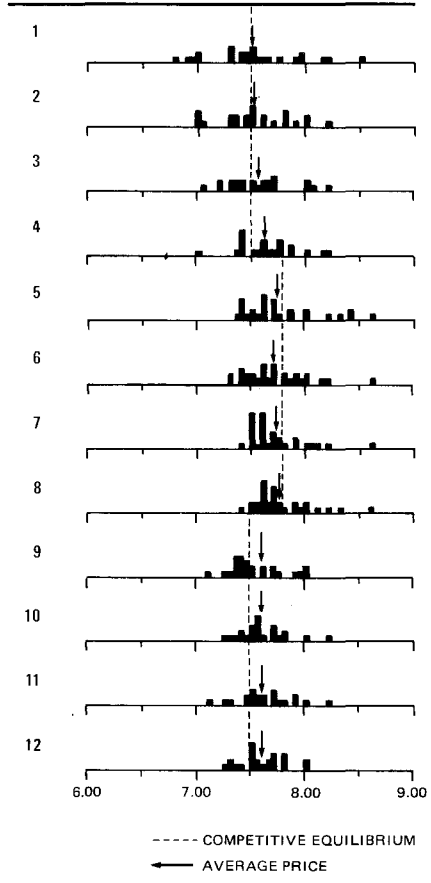
The very first market experiments, those reported by Chamberlin (1948) were negotiated price markets. Agents circulated in a room making contracts which were made public depending upon the treatment. The second study of negotiated price markets was reported by Hong and Plott (1982) in which the market was made through bilateral telephone conversations. Agents were located in separate offices. Buyers and sellers could call each other and discuss terms and/or agree on a contract price. Contact among buyers or among sellers was prevented so information about prices was limited. Buyers could shop at the cost of a (free) phone call.

The distribution of prices from Hong and Plott experiments is shown in Figure 19.8. 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 of contract prices 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 80–90 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) and Joyce (1983), 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 twenty-two 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.

The second study, by Grether and Plott (1984), 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 19.9, 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.



COMPETITIVE EQUILIBRIUM	ACTUAL AVERAGE	STANDARD DEVIATION	COMPETITIVE EQUILIBRIUM	ACTUAL	EFFICIENCY
$7.50	$7.51	$.416	21	25	83.0%
7.50	7.53	.332	21	24	88.9
7.50	7.57	.296	21	23	90.1
7.50	7.63	.280	21	22	89.2
7.80	7.75	.347	27	28	87.7
7.80	7.71	.293	27	30	87.3
7.80	7.74	.281	27	30	90.1
7.80	7.77	.265	27	30	95.8
7.50	7.59	.210	21	23	96.2
7.50	7.60	.226	21	23	95.8
7.50	7.61	.253	21	22	94.8
7.50	7.59	.206	21	23	94.4

Figure 19.8. Telephone market. *Source*: Plott (1982, p. 1497).

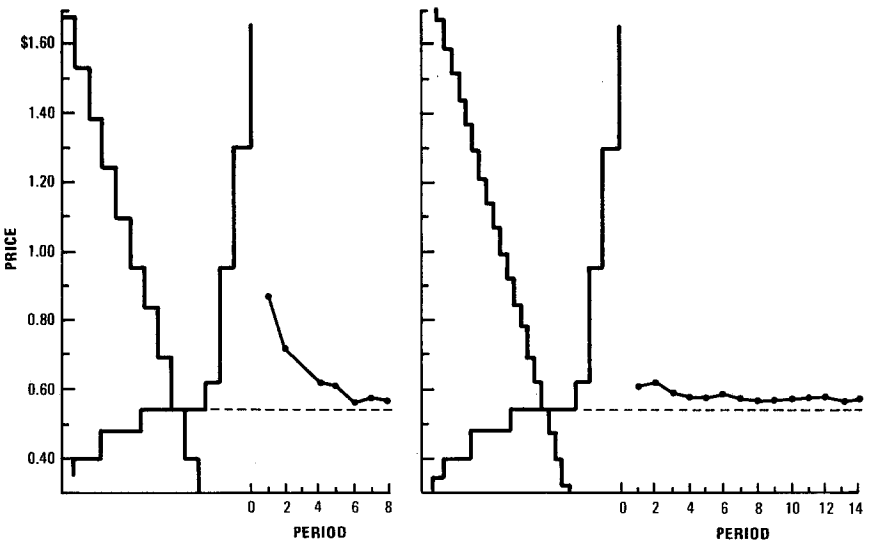


Figure 19.9. Average price per period for all periods in two markets. *Source*: Plott (1982, p. 1498).

A third study by Crössman (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. In these cobweb, unstable markets there exist no pronounced cycles.

The fourth and most recent study was by Joyce (1983). The Chamberlin mechanism of privately negotiated prices was compared to the oral double auction. Both of these mechanisms were further refined according to whether or not transactions were written on the chalkboard.[12] Three markets were conducted under each of the four market organizations giving a total of twelve markets. Average prices in all markets were close to the competitive equilibrium. The price variance was much higher in the negotiated price markets. Volume in the negotiated price markets was also higher. These findings are consistent with the other studies in which possible restrictions of information about alternative prices was a variable. Better information reduces price variance and tends to exclude extra marginal agents. The efficiency values of all four markets is high

[12]The exact timing of this public announcement is unclear for the Chamberlin mechanism conducted by Joyce. Presumably the announcement was made as soon as the deal was made during a period.

due, perhaps, to Joyce's choice of experimental parameters.[13] No substantial differences in efficiency are reported.

3.5. *Posted prices*

Posted-price research has tended to concentrate on mechanisms in which prices are privately posted and then made public. Once the prices are public, no discounting from published prices is permitted and prices cannot be changed for some suitable period of time. The process resembles a rate bureau more than an auction. In a posted offer (as opposed to posted bid) experiment, each seller submits a price, presumably in a sealed-bid fashion without benefit of consultation with other sellers. All prices are publicly posted, typically on a chalkboard, and cannot be changed by the seller for some fixed period. Buyers first approach the lowest priced seller, who can sell only at the posted price and who sells units until he wishes to sell no more at that price. As the low price sellers run out of stock, buyers move to the higher priced sellers. Since buyers will seek the low price advantages of the first buyer, a random device is usually applied to determine orderly access. After all buyers have had an opportunity to purchase, the period ends and sellers make pricing decisions for the next period.

The results of two experimental oral double auction markets are shown in Figure 19.10 in the upper right corner and the results of two experimental posted-offer markets are shown in the lower right. Each market consisted of four buyers and four sellers. The graph in the left of the figure is the market supply and demand model constructed from the parameters. The parameters of all markets were the same, but the participants differed. In the oral double auction markets, the average price during the first period is shown as the first dot and the average price during the second period is shown as the second dot. The price range during the period is the shaded area. Similar data are shown for the two posted-offer markets. The results are typical of data that have been generated by many replications.

Two aspects of the results are of interest. First, with repetition under fixed conditions, the market prices are near those predicted by the model, and efficiencies approach 90–100 percent. Second, prices tend to be higher for posted-price markets than for oral double auctions (about 10 cents higher in these markets) and efficiencies are lower. The efficiencies for the posted-price markets are in the low 90s, compared to 100 percent for the oral double auction markets.

The posted-price institution induces an upward pressure on prices. It also exerts a downward pressure on efficiency. This result signals a potential delicacy

[13]The markets had only one extramarginal unit. Furthermore, the "steps" in the functions were large ($0.20) so it was easy for extramarginal units to be excluded from trades.

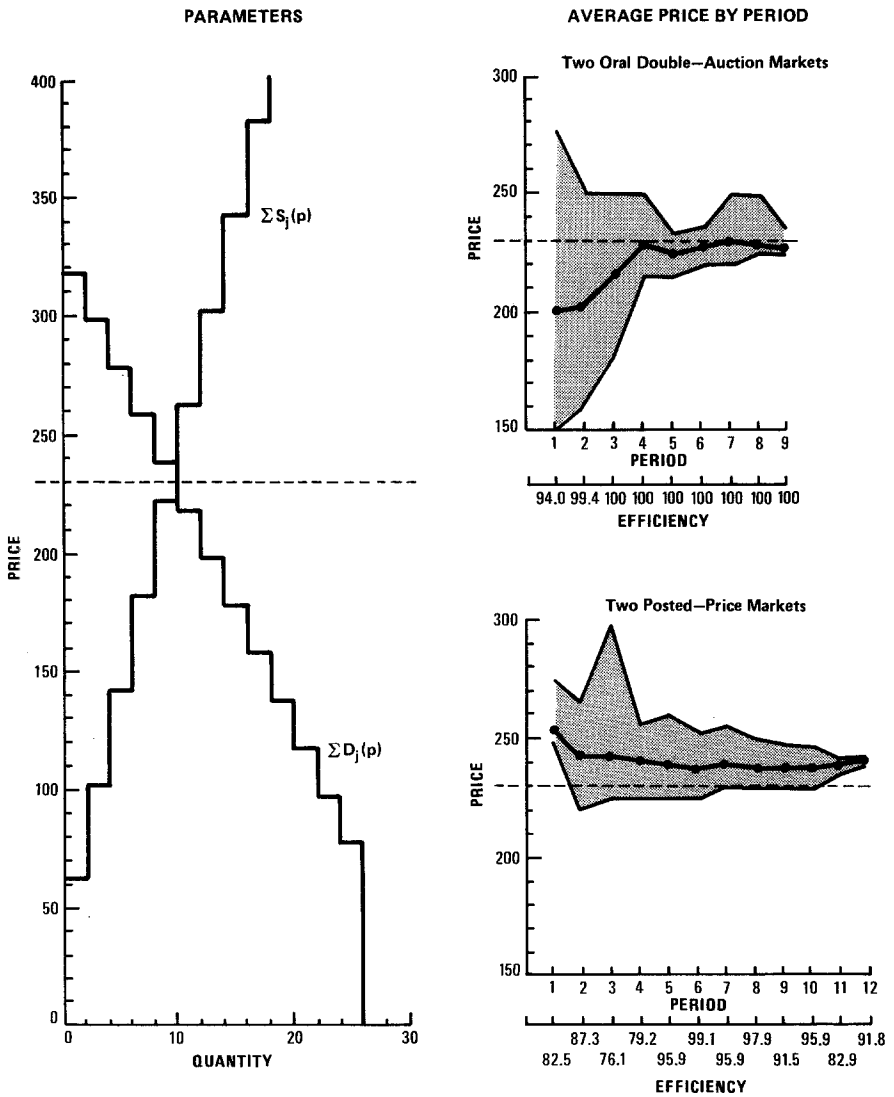


Figure 19.10. Parameters and average price per period for oral double auction and posted-price markets. *Source*: Plott (1986, p. 734).

in the market's performance by showing how it can be influenced by subtle features of organization.

The relative effect of the posted prices was first demonstrated by Plott and Smith (1978) in comparison experiments. The phenomenon had been observed earlier by F.E. Williams (1973) who believed that it was due to the fact that individuals could trade multiple units. Cook and Veendorp (1975) also observed the phenomenon and attributed it to asymmetries in information. Even now no theory about the influence of the posted-price institution has been published to my knowledge, but the effect has persisted under a variety of parametric situations. Extensive replications were made by Ketcham, Smith and A.W. Williams (1984). Markets with speculators were investigated by Hoffman and Plott (1981). Markets with a relatively large number of sellers were studied by Hong and Plott (1982). A variety of supply and demand configurations and asymmetries were studied by Davis and A.W. Williams (1984). The higher prices and lower efficiencies of posted-price markets, relative to the oral double auctions, have held up so far. In a more recent study Mestelman and Welland (1986) summarize the results of a series of projects [Mestelman, Welland and Welland (forthcoming), Mestelman and Welland (1987)] in which the production or supply decision was made prior to the opening of a market period. Thus, sellers were at risk. Under these conditions for the parameters they consider[14] the price differences between the double auction and the posted offer were not so evident. However the efficiency of the oral double auction is higher.

4. Imperfect competition

This section begins with a discussion of monopoly. A perfectly functioning cartel behaves as a monopoly, so in a sense monopoly is the polar case of oligopoly theory. Theories of imperfect competition must deal with the coordination of decisions among competitors, but the theory must also deal with the behavior of buyers. The buyers are not neutral in a market. Their actions tend to exacerbate the problems experienced by cartels, so the monopoly problem, where the natural coordination problem of oligopolists is absent, is a good place to begin.

4.1. Monopoly

Experiments with monopoly can be used to emphasize a fundamental theme that runs through experimental studies: the details of market organizations are

[14]Consumer surplus was greater than producer surplus which ordinarily places upward pressure on initial prices in the convergence process under the oral double auction. Of course, with advanced production the supply function in a period changes when the production decision is made. Cost becomes zero up to the supply, which creates a relative surplus that differs from the original parameters.

important to market performance. If organization matters, then can it be used to protect consumers against the natural advantages that are believed to characterize the position of a monopolist? Does the organization need to be in the form of direct regulation or will some sort of decentralized process do? The section reviews experiments with unregulated monopoly, regulated monopoly, and contested markets.

The difference in market performance when there exists several sellers under oral auctions, as opposed to posted prices, leads naturally to an inquiry about whether or not the behavior carries over to 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 a single unit 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 19.11 reproduces the time series from a particularly interesting experiment. It illustrates the difficulty of reaching any

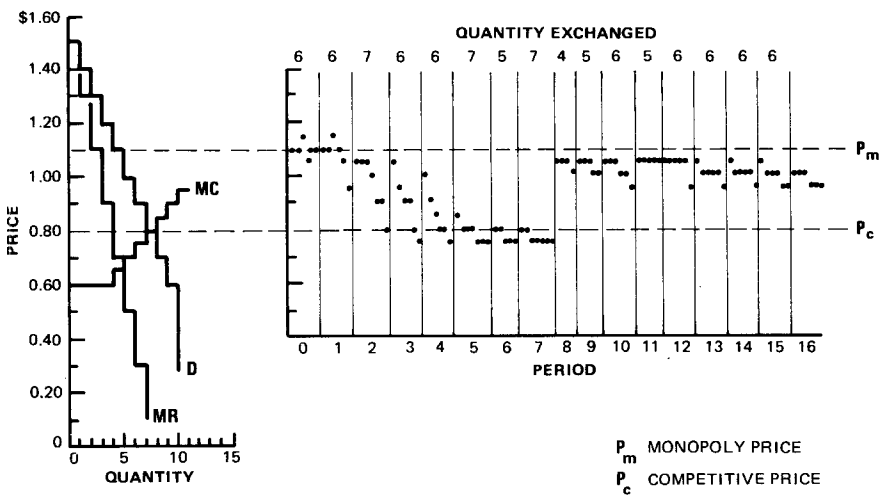


Figure 19.11. Double auction monopoly, where P_m = monopoly price, P_c = competitive price. *Source*: Smith (© 1981, Purdue Research Foundation, Chart 3, p. 91).

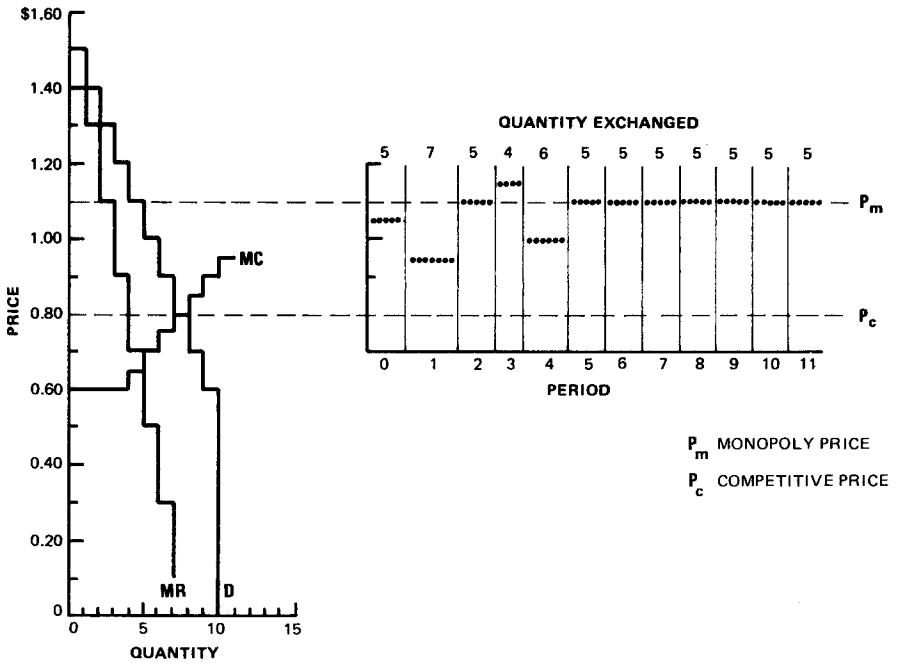


Figure 19.12. Posted offer monopoly, where P_m = monopoly price, P_c = competitive price. *Source*: Smith (© 1981, Purdue Research Foundation, Chart 5, p. 93).

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 asks) but, as will be shown below, certain institutions seem to prevent it and therefore help the monopolist.

In contrast, in posted-price (offer) markets 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 19.12. 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.[15] The

[15]"Counterspeculation" may be present but in these markets it was not sufficiently pronounced to be measurable.

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 single unit 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 study of natural monopolies has been initiated by Coursey, Isaac and Smith (1984) and Coursey, Isaac, Luke and Smith (1984). The focus of the two studies has been the possibility that "contestable" markets might provide a form of market control of monopoly. Between the two studies a total of twenty-two markets have been studied. In each market there were either one or two potential firms with identical declining average costs sufficient for the emergence of natural monopolies. Cost conditions at the individual firm level were such that marginal and average costs declined for ten units, after which further increases in supply were impossible. That is, marginal cost became infinite at the eleventh unit.

Demand price was above the average variable cost through the tenth unit when it was \$0.15 above the average variable cost of a firm producing ten units and \$1.00 below the average cost of a firm producing one unit.[16] A monopolist would theoretically sell six units[17] at a price of \$2.25 (\$1.15 above minimum average cost and exactly equal to the marginal variable cost of producing the first unit). The competitive outcome was ten units at \$1.25 (\$0.15 above minimum average variable cost) as will be described below.

In four control markets only one firm existed, which was an uncontested monopolist. For an additional six markets, two firms existed and entry costs (fixed costs) were zero. These markets thus provide an opportunity to study contestability in the absence of entry costs. For an additional twelve markets entry costs were \$2. This entry fee or fixed cost allowed a firm to operate for five periods without additional fixed costs. Firms that entered and paid the entry fee faced only variable costs. Firms "bid" for the market by submitting a price and a maximum quantity. In an order determined randomly buyers would then purchase from the seller of their choice.

A check of the parameters will reveal that the market can maintain two firms operating at two units each. However, the declining marginal costs place two firms in an unstable situation according to competitive theory. The competitive

[16] The continuous approximation of the variable cost function is $C(x) = \$2.50x - (\$0.125)x^2$ for $x \leq 10$ and $C(x) = \infty$ for $x > 10$. The continuous approximation of the demand function is $P = \$3.50 - \$0.25x$.

[17] Discontinuities in the functions dictated by practicalities of experimentation are responsible for the discrepancy between this number and the one produced by the continuous approximation.

equilibrium price, P_c, is the price that clears the market for the largest quantity that can be profitably sustained. Given the actual parameters the ten units capacity limitation is the maximum number that can be profitably sustained. If there are no fixed costs, then P_c is any price in the interval [1.10, 1.25]. In the experiments with entry costs the cost of entry was \$2.00 for a five-period term, so if ten units were sold per period, the entry cost is \$0.04 averaged over the units sold in the term. When entry costs are present, P_c is in the interval [1.14, 1.25].

Interest in the design stems from the fact that a plausible story can be made for any of several outcomes. Fear of a price war and resulting losses in the case of costly entry might prevent entry and allow a single firm to occupy the market and change monopoly prices. At the other end of the spectrum any profit of the existing firm might attract entry so prices are forced to stay in the competitive range. Or, prices might fluctuate wildly as entry and exit occurs. Or, in the case of the entry fee, neither firm might enter because of a fear of wars and losses or simply because of a lack of coordination. Of course, the market can hold both firms simultaneously if something like a "kinked demand curve" will keep prices up. The question posed by the experiments is which of the many competing ideas best capture the experience in these simple markets. If any model does well, the next natural question is to ask why?

The markets were organized as posted offer markets. Research reviewed above suggests that markets organized along these lines are most favorable to models of imperfect competition. However, even with the posted-offer institution buyers are not completely passive so in order to isolate the effects of contestability from other strategic features of market interaction, the demand side was simulated by a computer in most of the markets. The separation of the real buyers from simulated buyers was such that no confusion of results occurs.

The results are in Table 19.2. Without contestability the monopoly model best describes the data. Contestability with and without such costs does help control the monopolist. Furthermore, these markets showed no tendency to collapse in the sense that all firms withdrew from the market out of the fear of losses due to uneconomical entry. With sunk costs some unstable pricing was observed as firms attempted to change a monopoly price and attracted entry. Some limit pricing was observed with prices at or near the competitive range. In most periods the market was contested with two firms paying the fixed cost but one not producing because competition had lowered prices to the point of no profit from potential production and competition.

These results are only an initial probe into the behavior of contestable markets. The basic behavioral model is evolving toward those found successful in sealed-bid research. The fact that few players exist has implications that simply have not been touched by experiments. Clearly, the contestants would have an interest in mechanisms which would restrict the quantity that each offered to the market. Perhaps institutions or practices, which make the quantities offered public, along

Table 19.2
Number of experiments which on the eighteenth period were closer to the designated hypothesis

Hypothesis	Uncontested monopoly (total number of experiments = 4)	Contested market with entry cost = 0 (total number of experiments = 6)	Contested market with entry cost = \$2 (total number of experiments = 12)
Monopoly: $P > \frac{P_c + P_m}{2}$	4	0	0
Weak contestable: $P \leq \frac{P_c + P_m}{2}$	0	6	12
Strong contestable: $P \leq P_c$	0	4	6

Source: Coursey, Isaac, Luke and Smith (1984).

with the market demand functions and individual sales volumes, would help sellers coordinate decisions in a tacit collusion. Obviously such speculations can be addressed by further experiments.

While contestable markets constitute one form of organization that shifts the gains from exchange from the monopolist to consumers, other ideas exist. Theories of incentive regulation are just beginning to appear in the literature and experiments are being used to explore implementations of the theoretical ideas. Experimental work is continuously demonstrating that arguments that are simple in formal and mathematical terms can be very complicated or contradictory when made operational. The creation of simple types of otherwise abstract mechanisms involves such checks. Harrison and McKee (1985) began by investigating a regulatory scheme proposed by Loeb and Magat (1979). The scheme requires that regulators know the demand curve but not necessarily the cost curve of the monopolist. While the mechanism requires less information than, say, marginal cost pricing, it has the property (presumably undesirable) of requiring a large subsidy to be granted to the monopolist. The implementation chosen and tested by Harrison and McKee seemed to generate no surprises in that the processes worked approximately as advertised by the theory.[18] The mechanism guided

[18]Harrison and McKee called attention to an unusual aspect of their data. Subjects placed in the position of an uncontested monopoly, without regulatory complications, without random variables, and with simulated buyers who did not behave strategically, did not settle on the exact monopoly price. Because no subject ever chose the monopoly price, there must have been something complicated about the experimental environment that cannot be detected by simply reading the instructions used in the experiments. The existence of such inexplicable behavior compounds the usual problems encountered in attempts to generalize about experimental results.

choices in a manner that would protect consumers as was predicted by the theory, but substantial subsidies were required as indicated by the model. In order to avoid the subsidy problem Harrison and McKee devised a process that involves bidding for a franchise for the regulated monopoly thereby utilizing potential competition in a manner similar to the way it is used in the contestability literature. The franchise bidding scheme compares well to the performance of contested markets but of course it requires that the market demand function be known to the regulator.

Regulatory strategies were studied further by Cox and Isaac (1986) who were investigating alternatives to rate of return regulation for the Arizona Corporations Commission. They studied a proposal suggested by Finsinger and Vogelsang (1981) which does not require that the regulator know either the market demand function or the firm's cost function. In the markets Cox and Isaac created, the Finsinger and Vogelsang (FV) process demonstrated a potential for very perverse behavior. They describe the results as follows:

> The results of our FV series are a perfect example of how laboratory experimental tests of proposed regulatory institutions can be invaluable in public policy analysis. The theory states that this mechanism's optimal path will converge to the efficient outcome (in this case, an output of 12 units). But what happens if the firm errs, and gets off the optimal path? As Seagraves (1984) has noted, there is the possibility of such "cycles" adversely affecting the firm's profits. In fact, subject bankruptcy was a robust occurrence in our tests of the FV mechanism. [For example, in the second experiment]. ... the seller raised his price to $4.80 and then dropped it too quickly, becoming bankrupt. At this point, we cancelled his debts and went over with him step-by-step the path to his bankruptcy. Then, we told him that we would not cancel his debts again, but that we would be happy at any point to explain in advance the consequences of any decision he might want to make. Nevertheless, this seller again went bankrupt with a "Seagraves-cycle" in periods 10–11 ... .
>
> ... even though the FV mechanism has theoretically desirable optimal convergence properties, it is a mechanism which is permanently "unforgiving" of errors. In our laboratory markets, this feature proved to be important, with three of four sellers going bankrupt because of errors off the theoretically optimal path (p. 133).

This behavioral problem led Cox and Isaac to recommend against further consideration of the FV mechanism as a practical regulatory process. Unless an improved process can be found they did not think that the investigation would produce a process that they could comfortably recommend for a field trial.

4.2. Oligopoly

If monopoly, which is a perfectly coordinated cartel, has difficulty in attaining the monopoly profit position under the oral double auction, it should not be surprising that duopolists do much worse. After a brief review of the behavior of oligopolists' behavior in the absence of any type of facilitating device, the section turns to features of markets other than numbers that might make monopolizing behavior easier.

The analysis begins with the possibility that a harmony of interest is not easily recognizable by participants untrained to look for one. Perhaps agents automatically treat competitive situations as zero-sum games so the collusive predictions of some oligopoly theories never occur.

As it turns out, 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 asks, the bidding will sometimes start with a clearly unacceptable bid or ask (e.g. a bid of 1 cent or something far below any previously accepted price, or an ask from two to ten times higher than any previously accepted price). Such bids (asks) are often followed by similar bids (asks) 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 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.E. 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, asks, 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.

In two studies, focal points were given the opportunity to operate as collusive devices. In 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 [Scherer (1970, pp. 179–182)] 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, preperiod 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 19.13 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 measures exhibits some erratic behavior in the sense of a "pronounced" movement away from competitive equilibrium. In this sense the

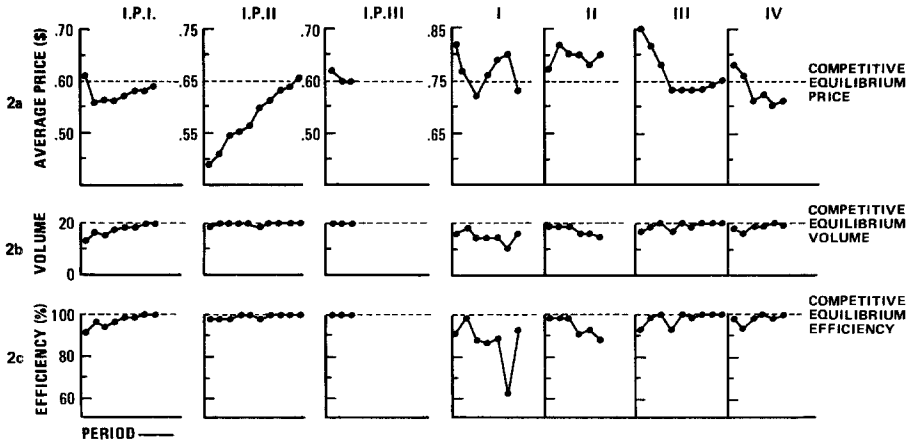


Figure 19.13. Average price, volume, and efficiency per period. *Source:* Isaac and Plott (1981a, Fig. 2, p. 10).

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 19.14 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][19] 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

[19] 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".

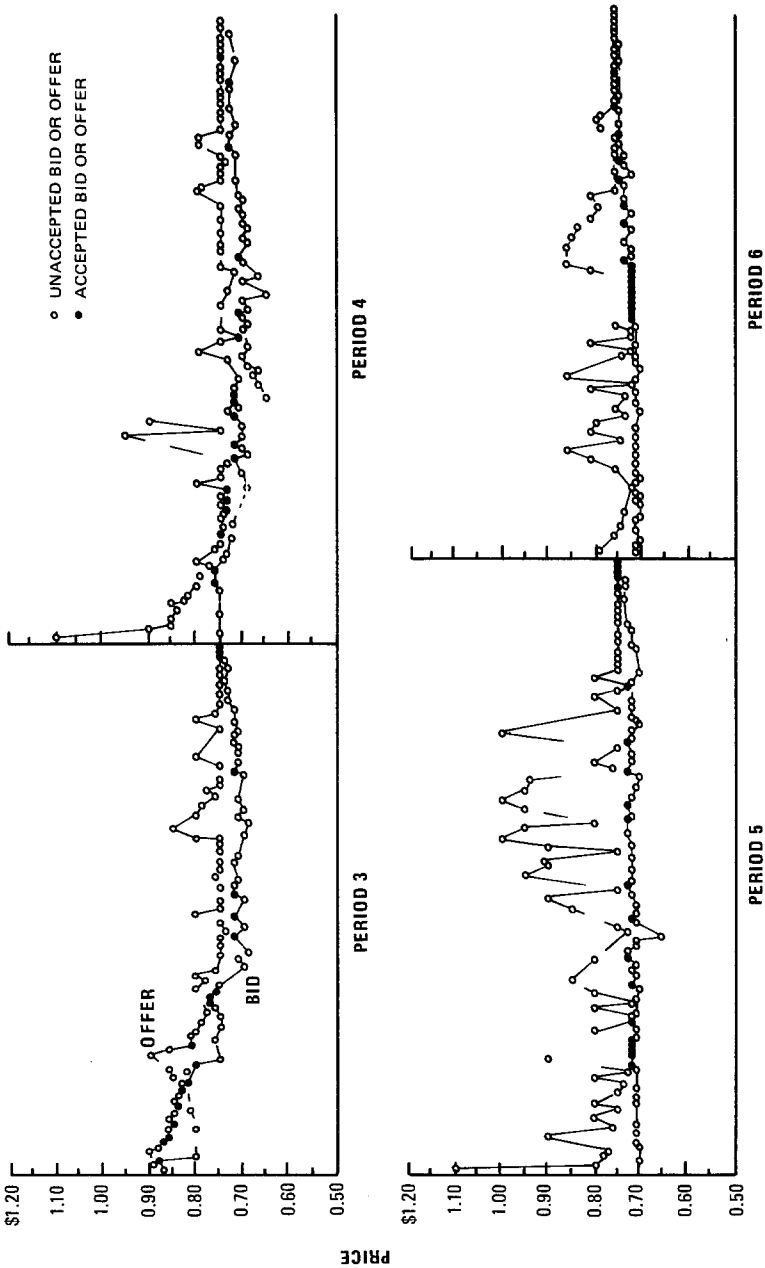


Figure 19.14. Experiment III – periods 3, 4, 5, and 6, all bids and offers. *Source:* Isaac and Plott (1981a, Fig. 11, p. 20).

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 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.

The properties of the oral double auction seem to carry over to negotiated price markets in which information is not as good. However, very little data exist currently. The only nonconspiratorial oligopoly markets that have been studied experimentally in which prices are privately negotiated are those in the Grether and Plott (1984) study. 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 (10–15 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 19.9. 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, buyers and/or sellers 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.

4.3. *Oligopoly and price posting*

Most experiments with oligopoly that have been conducted over a twenty-five year period can be interpreted as having (unknowingly) implemented the posted-price institution. Early experimenters [Hoggatt (1959), Fouraker and Siegel (1963)] gave subjects a profit table or its functional equivalent. The table contained the agents' profits expressed as a function of his/her own price and the price of a competitor. Sometimes the profit tables of both agents were public information. Such an experimental procedure removes from the picture all strategic behavior of the buyers and it reveals to the seller demand data that is privately held by buyers. It removes all price variance and it removes the opportunity to change strategies while market information is being generated. Since these are many of the behavioral features of posted price markets, most of the research that followed and that used profit tables to describe opportunities to subjects can be discussed in the context of price posting.

The resulting experimental literature is extensive and it has been reviewed in the paper from which this paper is developed [Plott (1982)] so it will not be reviewed again here. Instead, three of the prominent features will be listed. The chief results are that

(1) When there is imperfect information about actions or payoffs, prices converge to near the competitive equilibrium. When products were not "homogeneous", the Cournot model is the best of those examined.

(2) Full information about payoffs, symmetric payoffs, full information about opponents' choices, and very long periods of interaction tend to facilitate collusive behavior.

(3) The higher than competitive prices that is now known to be typical of posted prices in general seem to be observed in these early experiments.

More recent experiments that have utilized the same methodology with the market institutional framework simulated by a profit table have provided a deeper insight for the previously observed tendencies. Holt (1985) considered the possibility that the consistent equilibrium and not the Cournot equilibrium is the principle that lies behind the observed behavior. He noticed that almost all previous results could be interpreted in terms of the consistent-conjectures hypothesis as opposed to the Nash (Cournot) equilibrium model that had been used to interpret the results. He also felt that problems existed with the instructions used in early experiments and that special payoffs had biased the experiments against the consistent-conjectures equilibrium in those cases when the outcomes were not nearest to the consistent-conjectures equilibrium.

In a new series of experiments Holt adjusted the instructions and payoffs to correct for what he perceived to be biases against the consistent conjectures hypothesis. He chose parameters that clearly separated consistent-conjectures

equilibria from the Nash (Cournot) equilibria and he conducted the experiments with experienced subjects.

His results strongly support the Nash (Cournot) model over the consistent-conjectures equilibrium. He also observed some collusive behavior as had been observed in previous experiments with public and symmetric payoffs. The Holt experiments when added to previous work indicates that the Nash (Cournot) equilibrium is reasonably reliable in such environments and that the previous results strongly supporting the Nash model are not due to an accidental coincidence with the consistent-conjectures equilibrium.

A recent paper by Alger (1987) provides useful insights about the nature and importance of repeated game models. Alger, whose primary interest was in definitions of equilibrium and associated tests of equilibrium, designed experiments that push the limits of competitive equilibrium behavior. Given what is known about conditions under which monopoly results are likely, his parameters are a priori very favorable to monopoly behavior. Almost all of the markets were duopoly. Posted prices are used. Costs are identical. Costs are constant except for the first unit in a few cases. No commissions are paid so there is no incentive to trade marginal units at the competitive equilibrium prices. The experiments are conducted for as many as 160 periods.

The results after many periods appear to be bimodal (assuming that markets that attained a stable pattern of prices early at or near the Cournot equilibrium monopoly price would have sustained that price for the long term). Experiments were terminated after sufficient stationarity was observed. Most markets do not settle down to perfectly constant prices. Those that do so tend to be near the Cournot equilibrium, which in the Alger parameters is also near the monopoly level. Those that do not tend to be nearer the competitive equilibrium. The time path of competition is U-shaped. Prices tend to be high and converge downward. Once down near the competitive equilibrium, frequent attempts to get prices up are apparent. If prices ever gravitate up near the Cournot equilibrium or the monopoly price, the prices stick at a consistent level (on average but not universally). However, many never turn up and remain at relatively low levels with perfect stationarity of prices never occurring.

The upward bias of price posting occurs even when a "large" number of competitors exist. The upward pressure does not necessarily result in an edging of prices to the monopoly level as compared to the Cournot equilibrium even in very favorable underlying structural circumstances and many repeated trials. Posted prices facilitate the maintenance of prices at higher than competitive equilibrium levels but do not guarantee it.

A signal such as a nonbinding price control is not sufficient to coordinate competitors to move posted prices to monopoly levels. However, conspiracy in the presence of price posting appears to do the trick. Two papers begin the documentation needed. Sealed-bid markets are studied in Isaac and Walker

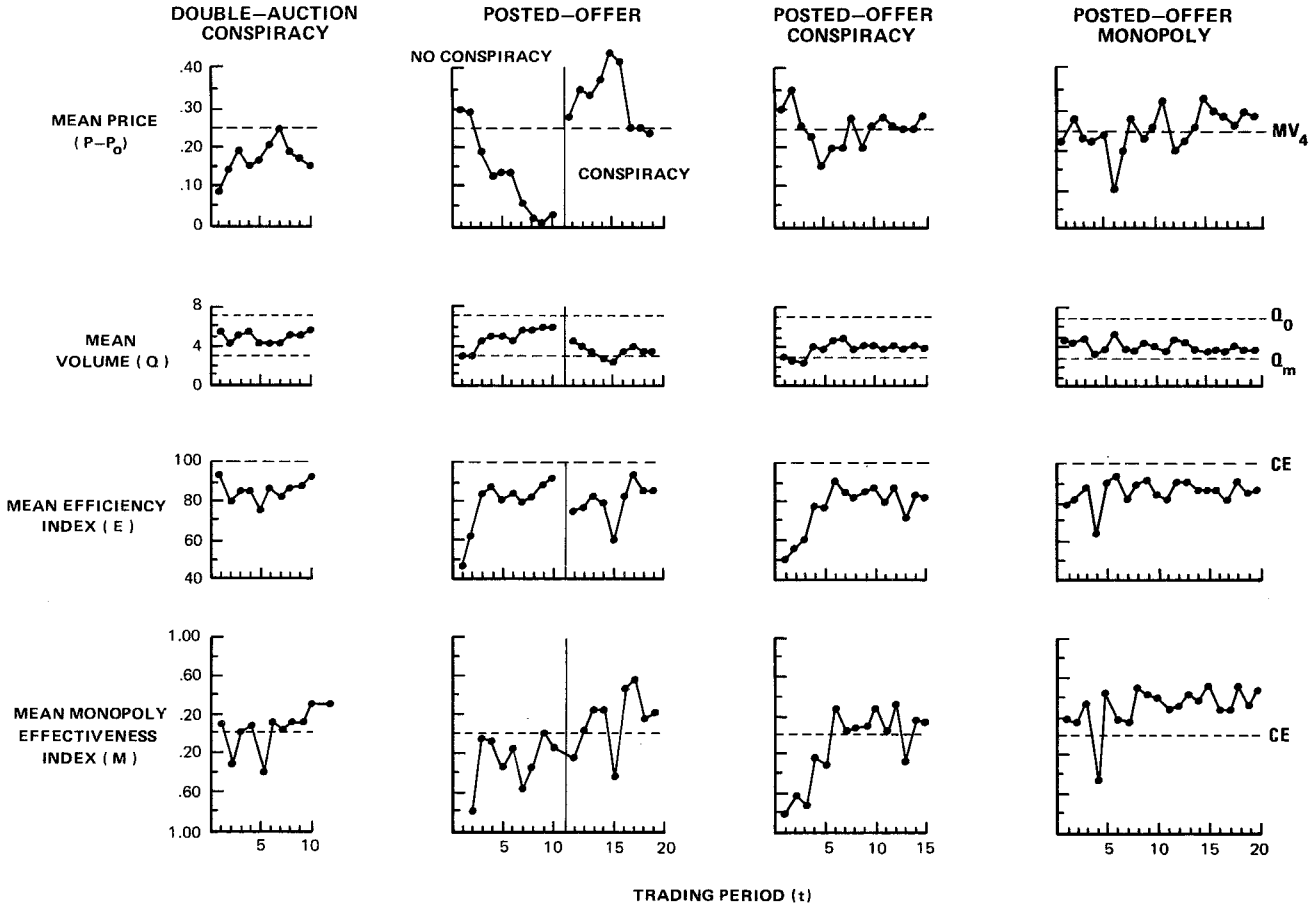


Figure 19.15. Comparison of market performance criteria. *Source:* Isaac, Ramey and Williams (1984, p. 217).

(1985). Conspiracies work to get prices to monopsony levels but the stability is fragile. Conspiracies in posted-offer markets are studied in Isaac, Ramey and Williams (1984). Figure 19.15 shows comparison experiments between double auction conspiracy and posted-offer conspiracy. Posted-offer monopoly and posted-offer no-conspiracy are controls. Double auction no-conspiracy controls are unnecessary since it is known that the behavior is captured adequately by the competitive model.

The conspiracies could fix prices but no side payments were permitted. The price P_m is the monopoly price but at this price one of the sellers would be excluded from the market with zero profit. The price MV_4 is the highest price that keeps all sellers in the market. The figure shows the average of the four experiments conducted under each treatment.[20] The index of monopoly effectiveness is the difference between actual sellers' profit and the profits they would have made at the competitive equilibrium taken as a percentage of the maximum possible difference.

The behavior of conspiracy with posted prices was substantially the same as was the behavior of the monopolists under posted prices. However, both forms of organization fell short of achieving the full monopoly price. On the other hand posted-price conspiracies are more effective than are double auction conspiracies.

The results of these experiments add more data to answer the questions about conspiracy originally posed by Isaac and Plott (1981a). Do trades recognize a harmony of interest? Will they attempt to collude when given the opportunity? Can they formulate an agreement? The answer to those three questions is clearly yes, but the answer to the next two questions depends upon the nature of facilitating devices. Once an agreement is formulated, do they try to implement it in the market? Does the attempted implementation affect the market? If the institution is posted prices, the answer is clearly yes.

4.4. Markets with advance notification and price protection

The recent actions taken by the Federal Trade Commission[21] have drawn attention to the market institution in the antiknock compound industry.[22] 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

[20] The no-conspiracy treatment under posted offer involved only two experiments. The behavior of these two is typical of the many others that have been conducted.

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

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

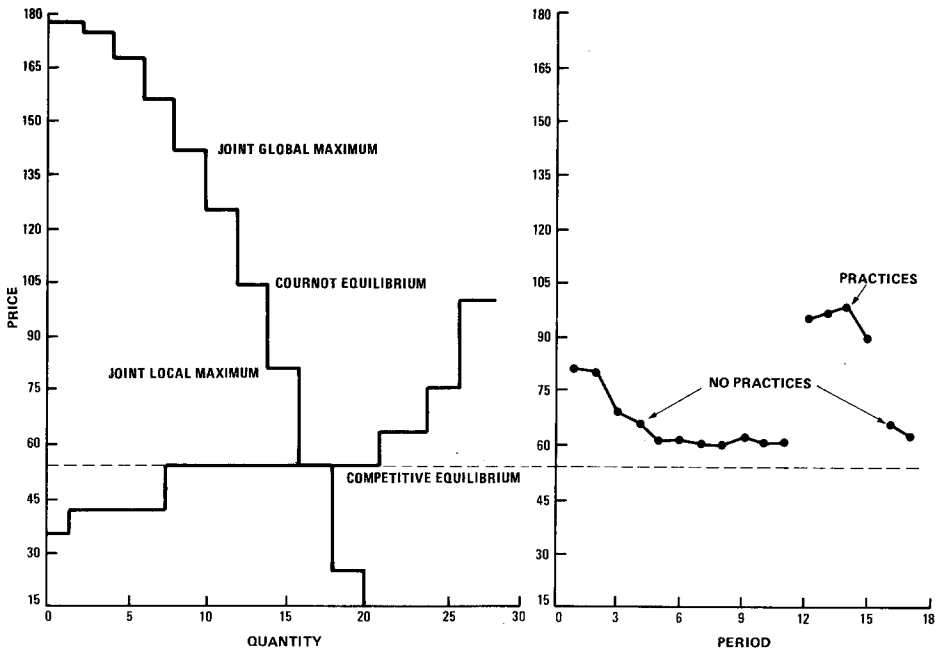


Figure 19.16. Parameters and average price per period. *Source:* Plott (1982, p. 1519).

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 (1979, 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 19.16.

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 19.16 gives the average 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 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.

5. Product quality

Only recently have studies of product quality begun to appear in the experimental literature. The delay reflects the fact that markets with variable product quality are actually multiple markets. Each level of quality is in essence a

separate commodity so experimentation requires an extension of the methodology to (potential) multimarket processes. As experiments with the operation of multimarket systems began to grow,[23] markets with variable product qualities began to appear.

One of the primary objectives of some of the early experiments was to create markets that would reliably fail. Failure means only one quality product would be supplied even though social efficiency calls for a different quality to be supplied. The research strategy was clear. Perhaps by studying markets that fail, better insight about the behavioral principles that lead to failure could be gained. More importantly, observed market failures must be available if policies intended to correct failures are to be studied. In other words the research has been an attempt to create something that was broken in order to study the reliability of broad policies intended to get things fixed.

A key feature of markets with quality variability is asymmetric information between the buyers and sellers. Generally the seller knows something that the buyer would like to know and the seller also has a self-interest in the buyer's decisions. Plott and Wilde (1982) explored this type of relationship within experimental markets that had some of the prominent features of markets in which professional diagnosis plays a special role. The study was commissioned by the Federal Trade Commission (FTC) which reviews the behavior of such markets and from time to time considers regulatory actions. The idea was to create a market that failed in the theoretical sense and use it as a baseline to study tools used by the FTC to detect failures and as a baseline for additional experiments with policies under consideration by the FTC. The interesting result from this study is that markets which were designed to fail according to guidelines provided by existing theory actually failed to fail. The markets worked very well even though they were not supposed to work well according to accepted theory.

Buyers were given redemption values of the form $V^i(x_i, \theta_i)$, where $x_i \in \{X, Y\}$ and $\theta_i \in \{A, B\}$.[24] For each agent the probability that θ_i took value A and B was respectively $1/3$ and $2/3$. In addition, for each i a clue was available. It was a sample of twelve independent observations of a random variable $s_i \in \{0, I\}$ with prob$(0|A) = 1/4$ and prob$(0|B = 1/3)$.

[23] Multiple market experiments began with R. Miller, Plott and Smith (1977) in which the economy had two markets separated in time. Speculators could buy in one market and sell in the other. Many studies in the field of finance have extended the multimarket research. Four markets with complements were studied in Grether, Isaac and Plott (1981, forthcoming). The basic technology for studying multimarket systems is in place but the dynamics and other features of equilibration remain open questions.

[24] $V^i(X, A) = V^i(X, B) = \$1.55 = V^i(Y, B)$; $V^i(Y, A) = \$9.45$. These values reflect the idea that X will always "help" a problem and so is a valuable thing to purchase. However, if the individual is in state A, commodity Y is of much greater value than is X.

Under one condition, the professional diagnosis condition, the functions prob(θ_i) and prob($s_i|\theta_i$) were known only to the seller and the sample of twelve observations was known only to the seller.[25] Thus, the seller was in a position to evaluate the posterior probability of θ_i given s_i and had been trained in earlier sessions to make guesses about θ given the sample information s. Each period a draw of θ was determined for each buyer. The clue was issued and the buyer would purchase either an X or a Y after having sought the advice of one or more sellers. The accuracy of the advice was not learned by buyers until the end of the entire experiment which consisted of several periods and associated purchases.

Under a second condition, the self-diagnosis condition, buyers were trained with the probabilistic mechanism used to determine θ and s. Buyers had the training and practice in guessing θ_i given s_i. Buyers also had the information contained in the signal s_i. So in the self-diagnosis case buyers relied on sellers for nothing other than the units that sellers sold.

Prices were determined competitively.[26] The rents were greater for the Y at prices near competitive levels so sellers had an interest in selling the Y commodity.

The condition of professional diagnosis involves an obvious conflict of interest on the part of sellers. Buyers have no direct information on which to assess the professional abilities of the seller. One might reasonably expect sellers to recommend Y, the most profitable item. They could do this by diagnosing the state of the individual customer to be A, which makes Y the most desired item from the buyer's point of view. The "big lie" hypothesis was that sellers would recommend the most profitable item. Buyers unable to ever directly check the quality of the diagnosis would be induced to buy an expensive item that was unneeded. According to the "big lie" hypothesis, Y sales under the professional-diagnosis condition would exceed Y sales under the self-diagnosis condition.

The surprising result was that the "big lie" hypothesis was rejected. The "market failure" that was expected and the resulting flood of "lemons" that was expected did not occur. In fact, the markets in which buyers made their own diagnoses performed worse in an expected value of surplus sense than did markets in which the buyers were forced to rely on information provided by the sellers. The result was summarized by Plott and Wilde (1982, p. 97) as follows:

> Seller advice seems to be governed by systematic competitive principles similar to those which govern price competition. In particular, there seems to emerge a "uniform recommendation" depending strictly upon the clue (or symptoms) similar to the principle of "one price" in a market. The intuition behind the

[25] Each period each buyer was given a card that could only be seen by the seller. The card contained the sample of twelve observations of s_i.

[26] The market organization was not the oral double auction. The paper should be consulted for the details.

conjecture stems from the apparent low variance of advice across sellers and the possible tendency for buyers to avoid purchasing from sellers who deviated far from the "mean recommendation". Thus sellers who wish to make sales *at all* (of either the low-profit item or the high-profit item) must give advice similar to other sellers, and in the absence of collusion the best strategy is the "truth" as seen by the seller. This proposed principle of "truthful, uniform recommendations" is subject to at least the three qualifications listed below. This general thesis (along with the qualifications) can be explored by further experimentation.

Markets with lemons have been successfully created by Lynch, Miller, Plott and Porter (1986). The conditions were similar to "experience" goods whose quality was endogenously determined. Buyer and seller identifications were unknown to transacting parties.[27] Sellers had a total capacity limitation of two units to sell per period. After a sale and prior to delivery, sellers would choose the grade of the unit to be either regular or super. Costs to the seller were constant with the cost of supers being higher than the cost of regulars. The grade of all units delivered was public. Buyers preferred supers to regulars. The market was conducted for several periods.

Figure 19.17 tells much of the story. Market demands and supplies for supers and regulars are drawn as they would be if only one grade was offered for sale. The lemons' allocation is that all units are regulars and the equilibrium is a price just below 165. The efficient allocation, which is preferred to the lemons' allocation by all buyers and all sellers, is that all units be supers. The equilibrium price would be just below 300. The time series of trades shows that prices start high and the low-grade lemons are delivered. (Regulars are indicated by a dot and supers are indicated by an X.) Prices fall reflecting the fact that buyers fully anticipate the low quality. The quality is poor but buyers are not being misled.[28] In period 7 a costlessly enforceable warranty is made available to sellers. When this instrument exists, competition forces its use and as can be seen the equilibrium almost immediately shifts to the sale of supers. Efficiency jumps to near 100 percent. Buyers avoid units without the warranty even when low priced, and if they purchase such a unit, they expect the low quality. The power of costlessly enforced warranties is clear.[29] It removes uncertainty and the economy functions as a general equilibrium system might be expected to.

When seller identifications were known so reputations were possible, market quality improved. The backward induction hypothesis, which theoretically leads

[27]Buyers were in one room and sellers were in another. Bids and asks, which were unrestricted and remained open until accepted or canceled, were transmitted by a citizen's band radio.

[28]In some experiments false advertising was allowed. Most sellers falsely advertised but buyers were not misled in the sense that prices stayed near the lemons' equilibrium.

[29]In the experiment the instrument was an express warranty.

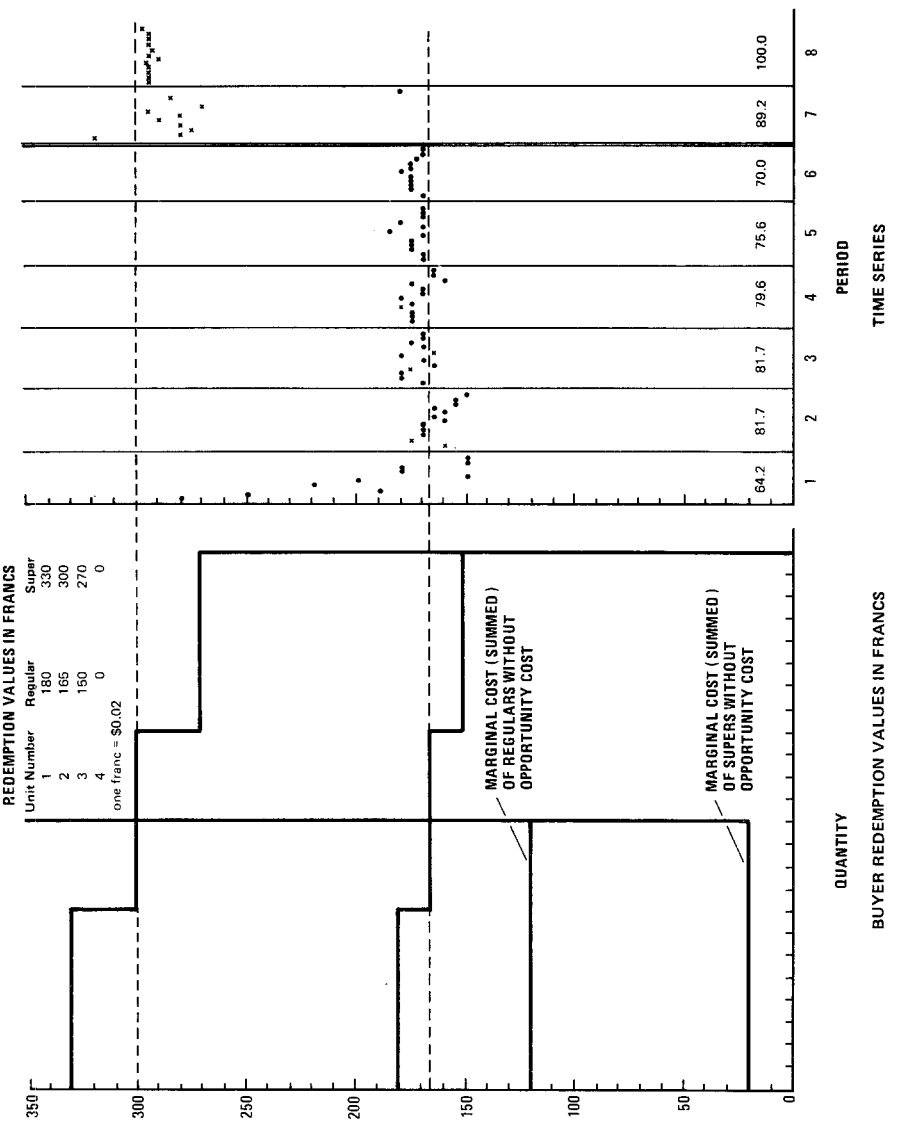


Figure 19.17. *Source:* Lynch et al. (1986, Fig. 1, p. 254, and Fig. 11, p. 275).

to lemons in these finite period markets (because of the repeated prisoner's dilemma nature of the situation), does not work. Attempts to establish reputations can be seen, but many things make reputation formation difficult in the absence of instruments like warranties. Sellers who wish reputations must first deliver quality units at low prices and thus suffer the (hopefully) temporary losses.[30] The magnitude of loss depends upon the speed of market adjustment to the high prices necessary to support high quality. Once quality is established at high prices, the price itself serves as a signal, thereby allowing competitors to free ride on the reputation building investments of the high-quality sellers. Sellers who decide to "cash in" on reputations and deliver lemons at high prices create an external diseconomy on sellers who are attempting to maintain a reputation as buyers shy away from all high-priced sellers for fear of being burned. Briefly put, reputation development can be important but the dynamics by which this occurs in the laboratory environments involves many aspects not captured by current theory.

Markets in which special product characteristics (e.g. the terms of warranties) are endogenously determined in response to asymmetric information about quality features that are exogenously determined have been the focus of three additional studies. In the first study, by Palfrey and Romer (1986), sellers were able to choose one of three types of warranties that covered the units.[31] A commodity thus became an underlying grade that was exogenously determined by an underlying randomness and a warranty package that protected the buyer in various ways. The study also implemented dispute resolution mechanisms that differed according to the party that bore the cost of the mechanism. The study is useful as an attempt to construct a laboratory environment with a variety of warranty instruments and as an initial study to determine which instrument survived. An insufficient amount of experimentation prevents solid conclusions but the warranty offerings differed from predictions. According to the model, one type of warranty should drive out the other type. As it turns out, both types of warranties survived. Palfrey and Romer remain somewhat perplexed by the results and initiated some tests of "subrational" models. The price data support a Bayesian equilibrium model as opposed to a "myopic" learning model. No definitive results are offered.

In the second study, Holt and Sherman (1986) study bundling decisions in response to uncertainty. Under certain cost and uncertainty conditions, bundling of commodities by sellers in a "take it all or leave it all" unit can be the most efficient base for transactions as opposed to selling each unit separately. The average quality can be provided more reliably for a bundle than for an individual

[30] If prices are not near the cost of the low-quality units then the profitability of high-quality production may be insufficient to make reputation development worthwhile.

[31] In some experiments only two types of warranties were available.

unit. The bundling is a response to an underlying randomness. A total of four experiments were conducted. The efficient commodity type tended to emerge in all four.

The third study, by R. Miller and Plott (1985), also involved units of exogenously determined grade. Sellers observed the underlying grade (regular or super) but buyers could not. Sellers could make units more valuable by adding amounts of "quality". Since the amount of quality added could vary from 0 to 1000, a very large number of potential commodities existed in the market. The marginal cost of adding quality was higher for units of grade regular than for units of grade super. Demand and cost conditions were such that signaling equilibria existed in appropriately applied signaling models. The general tendency in the markets studied was for the quality added to serve as a signal for the underlying grade. Several markets approached the most efficient signaling equilibrium. The approach to equilibrium was from the direction of excess quality.

6. Defense of experiments[32]

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 purse 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.[33]

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.

[32]This section of the paper is reproduced from Plott (1982, pp. 1519–1523).
[33]See Plott (1979, 1987) and Smith (1980, 1982) for a detailed discussion.

6.1. *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".

6.2. *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.

6.3. *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 of the model under parametric perturbations such as number of competitors, demand elastic-

ity, 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.

6.4. 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.

6.5. 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 experiments 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. Physical scientists must deal with it and so must 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 the 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, should not these magnitudes 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 word 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.

7. Closing remarks[34]

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

[34]This section is reproduced from Plott (1982, pp. 1523–1524).

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 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[35] 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 purse, and frequently the choices must be based on very thin data and controversial economic 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 quick source of data. How these data will be regarded by the courts is yet to be determined [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

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

claims checks places severe veracity constraints upon those who might enter such data as evidence in a court proceeding.

Appendix: Instructions

A.1. General

This is an experiment in the economics of market decisionmaking. The instructions are simple and if you follow them carefully and make good decisions you might earn money which will be paid to you in cash.

In this experiment we are going to conduct 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.

The currency in these markets is francs. Each franc is worth _____ dollars to you.

A.2. 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 (4) 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. That is,

$$[\text{your earnings} = (\text{redemption value}) - (\text{purchase price})].$$

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:

$$\text{earnings from first} = 200 - 150 = 50$$

$$\text{earnings from second} = 180 - 160 = 20$$

$$\text{total earnings} = 50 + 20 = 70$$

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 row (3). At the end of the period record the total of profits on the last row on the page. Subsequent periods should be recorded similarly.

A.3. 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 row (2) marked *cost of 1st unit*; if you sell a second unit you incur the cost listed in row (5) marked *cost of 2nd 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 the unit and the cost of the unit. That is,

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

Suppose, for example, your cost of the first 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 first = 200 − 140 = 60

earnings from second = 190 − 160 = 30

total earnings = 60 + 30 = 90

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

A.4. Market organization (multiple unit ODA)

The market for units is organized as follows. The trading period is open for_____minutes. Any person is free to bid, to buy (ask to sell) at any time that recognition is gained from the auctioneer. The bid (ask) is tendered by giving the sequence: name, bid price per unit (ask price per unit), quantity. The bid (ask) will be written on the chalkboard and will remain there until accepted, canceled

or replaced by a higher (lower) bid (ask). Anyone is free to accept any part of a standing bid (ask) and the remainder continues to stand. If a person accepts all or part of a bid (ask), a binding contract has been closed and both parties must record the transaction.

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