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AN EXPERIMENTAL STUDY OF COMPETITIVE MARKET BEHAVIOR[1]

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I. INTRODUCTION

RECENT years have witnessed a growing interest in experimental games such as management decision-making games and games designed to simulate oligopolistic market phenomena. This article reports on a series of experimental games designed to study some of the hypotheses of neoclassical competitive market theory. Since the organized stock, bond, and commodity exchanges would seem to have the best chance of fulfilling the conditions of an operational theory of supply and demand, most of these experiments have been designed to simulate, on a modest scale, the multilateral auction-trading process characteristic of these organized markets. I would emphasize, however, that they are intended as simulations of certain key features of the organized markets and of competitive markets generally, rather than as direct, exhaustive simulations of any particular organized exchange. The experimental conditions of supply and demand in force in these markets are modeled closely upon the supply and demand curves generated by the limit price orders in the hands of stock and commodity market brokers at the opening of a trading day in any one stock or commodity, though I would consider them to be good general models of received short-run supply and demand theory. A similar experimental supply and demand model was first used by E. H. Chamberlin in an interesting set of experiments that pre-date contemporary interest in experimental games.[2]

[1] The experiments on which this report is based have been performed over a six-year period beginning in 1955. They are part of a continuing study, in which the next phase is to include experimentation with monetary payoffs and more complicated experimental designs to which passing references are made here and there in the present report. I wish to thank Mrs. Marilyn Schweizer for assistance in typing and in the preparation of charts in this paper, R. K. Davidson for performing one of the experiments for me, and G. Horwich, J. Hughes, H. Johnson, and J. Wolfe for reading an earlier version of the paper and enriching me with their comments and encouragement. This work was supported by the Institute for Quantitative Research at Purdue, the Purdue Research Foundation, and in part by National Science Foundation, Grant No. 16114, at Stanford University.

[2] "An Experimental Imperfect Market," *Journal of Political Economy*, LVI (April, 1948), 95–108. For an experimental study of bilateral monopoly, see S. Siegel and L. Fouraker, *Bargaining and Group Decision Making* (New York: McGraw-Hill Book Co., 1960).

Chamberlin's paper was highly suggestive in demonstrating the potentialities of experimental techniques in the study of applied market theory.

Parts II and III of this paper are devoted to a descriptive discussion of the experiments and some of their detailed results. Parts IV and V present an empirical analysis of various equilibrating hypotheses and a rationalization of the hypothesis found to be most successful in these experiments.

Part VI provides a brief summary which the reader may wish to consult before reading the main body of the paper.

II. EXPERIMENTAL PROCEDURE

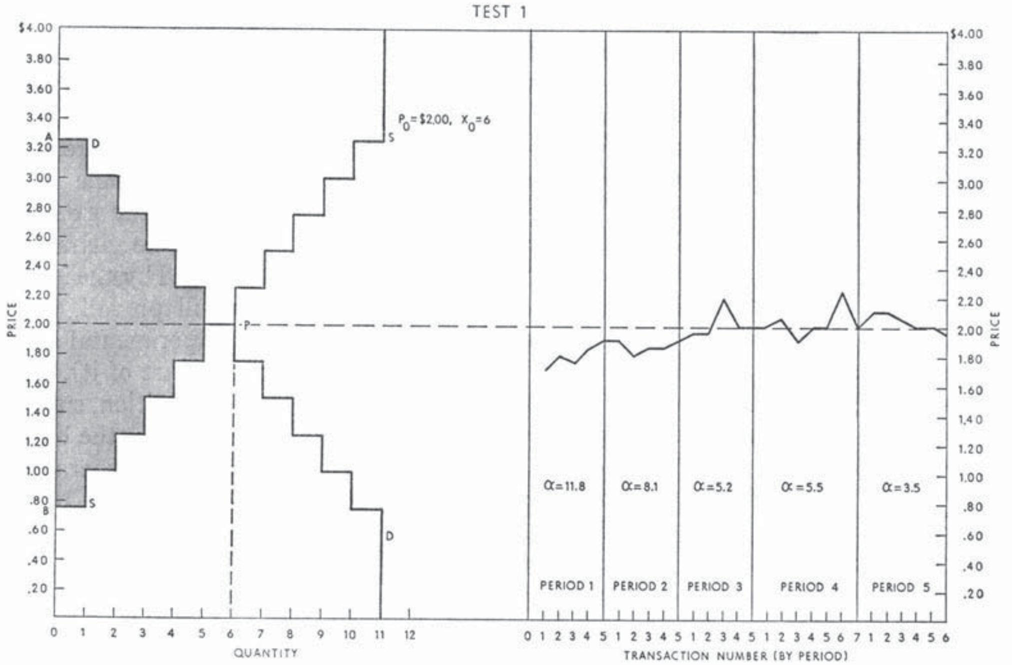
The experiments discussed in Parts III and IV have followed the same general design pattern. The group of subjects is divided at random into two subgroups, a group of buyers and a group of sellers. Each buyer receives a card containing a number, known only to that buyer, which represents the maximum price he is willing to pay for one unit of the fictitious commodity. It is explained that the buyers are not to buy a unit of the commodity at a price exceeding that appearing on their buyer's card; they would be quite happy to purchase a unit at any price below this number—the lower the better; but, they would be entirely willing to pay just this price for the commodity rather than have their wants go unsatisfied. It is further explained that each buyer should think of himself as making a pure profit equal to the difference between his actual contract price and the maximum reservation price on his card. These reservation prices generate a demand curve such as *DD* in the diagram on the left in Chart 1. At each price the corresponding quantity represents the maximum amount that could be purchased at that price. Thus, in Chart 1, the highest price buyer is willing to pay as much as \$3.25 for one unit. At a price above \$3.25 the demand quantity is zero, and at \$3.25 it cannot exceed one unit. The next highest price buyer is willing to pay \$3.00. Thus, at \$3.00 the demand quantity cannot exceed two units. The phrase "cannot exceed" rather than "is" will be seen to be of no small importance. How much is actually taken at any price depends upon such important things as how the market is organized, and various mechanical and bargaining considerations associated with the offer-acceptance process. The demand curve, therefore, defines the set (all points on or to the left of *DD*) of possible demand quantities at each, strictly hypothetical, ruling price.

Each seller receives a card containing a number, known only to that seller, which represents the minimum price at which he is willing to relinquish one unit of the commodity. It is explained that the sellers should be willing to sell at their minimum supply price rather than fail to make a sale, but they make a pure profit determined by the excess of their contract price over their minimum reservation price. Under no condition should they sell below this minimum. These minimum seller prices generate a supply curve such as *SS* in Chart 1. At each hypothetical price the corresponding quantity represents the maximum amount that could be sold at that price. The supply curve, therefore, defines the set of possible supply quantities at each hypothetical ruling price.

In experiments 1–8 each buyer and seller is allowed to make a contract for the exchange of only a single unit of the commodity during any one trading or market period. This rule was for the sake of simplicity and was relaxed in subsequent experiments.

Each experiment was conducted over a sequence of trading periods five to ten minutes long depending upon the number of participants in the test group. Since the experiments were conducted within a class period, the number of trading periods was not uniform among has been closed, and the buyer and seller making the deal drop out of the market in the sense of no longer being permitted to make bids, offers, or contracts for the remainder of that market period.[3] As soon as a bid or offer is accepted, the contract price is recorded together with the minimum supply price of the seller

CHART 1



the various experiments. In the typical experiment, the market opens for trading period 1. This means that any buyer (or seller) is free at any time to raise his hand and make a verbal offer to buy (or sell) at any price which does not violate his maximum (or minimum) reservation price. Thus, in Chart 1, the buyer holding the $2.50 card might raise his hand and shout, "Buy at $1.00." The seller with the $1.50 card might then shout, "Sell at $3.60." Any seller (or buyer) is free to accept a bid (or offer), in which case a binding contract and the maximum demand price of the buyer involved in the transaction. These observations represent the recorded data of the experiment.[4] Within the time limit

[3] All purchases are for final consumption. There are no speculative purchases for resale in the same or later periods. There is nothing, however, to prevent one from designing an experiment in which purchases for resale are permitted if the objective is to study the role of speculation in the equilibrating process. One could, for example, permit the carry-over of stocks from one period to the next.

[4] Owing to limitations of manpower and equipment in experiments 1–8, bids and offers which did not lead to transactions could not be recorded. In subsequent experiments a tape recorder was used for this purpose.

of a trading period, this procedure is continued until bids and offers are no longer leading to contracts. One or two calls are made for final bids or offers and the market is officially closed. This ends period 1. The market is then immediately reopened for the second "day" of trading. All buyers, including those who did and those who did not make contracts in the preceding trading period, now (as explained previously to the subjects) have a renewed urge to buy one unit of the commodity. For each buyer, the same maximum buying price holds in the second period as prevailed in the first period. In this way the experimental demand curve represents a demand per unit time or per trading period. Similarly, each seller, we may imagine, has "overnight" acquired a fresh unit of the commodity which he desires to sell in period 2 under the same minimum price conditions as prevailed in period 1. The experimental supply curve thereby represents a willingness to supply per unit time. Trading period 2 is allowed to run its course, and then period 3, and so on. By this means we construct a prototype market in which there is a flow of a commodity onto and off the market. The stage is thereby set to study price behavior under given conditions of normal supply and demand.[5] Some buyers and sellers, it should be noted, may be unable to make contracts in any trading period, or perhaps only in certain periods. Insofar as these traders are submarginal buyers or sellers, this is to be expected. Indeed, the ability of these experimental markets to ration out submarginal buyers and sellers will be one measure of the effectiveness or competitive performance of the market.

The above design considerations define a rejection set of offers (and bids) for each buyer (and seller), which in turn defines a demand and a supply schedule for the market in question. These schedules do nothing beyond setting extreme limits to the observable price-quantity behavior in that market. All we can say is that the area above the supply curve is a region in which sales are feasible, while the area below the demand curve is a region in which purchases are feasible. Competitive price theory asserts that there will be a tendency for price-quantity equilibrium to occur at the extreme quantity point of the intersection of these two areas. For example, in Chart 1 the shaded triangular area APB represents the intersection of these feasible sales and purchase sets, with P the extreme point of this set. We have no guarantee that the equilibrium defined by the intersection of these sets will prevail, even approximately, in the experimental market (or any real counterpart of it). The mere fact that, by any definition, supply and demand schedules exist in the background of a market does not guarantee that any meaningful relationship exists

[5] The design of my experiments differs from that of Chamberlin (*op. cit.*) in several ways. In Chamberlin's experiment the buyers and sellers simply circulate and engage in bilateral higgling and bargaining until they make a contract or the trading period ends. As contracts are made the transaction price is recorded on the blackboard. Consequently, there is very little, if any, multilateral bidding. Each trader's attention is directed to the one person with whom he is bargaining, whereas in my experiments each trader's quotation is addressed to the entire trading group one quotation at a time. Also Chamberlin's experiment constitutes a pure exchange market operated for a single trading period. There is, therefore, less opportunity for traders to gain experience and to modify their subsequent behavior in the light of such experience. It is only through some learning mechanism of this kind that I can imagine the possibility of equilibrium being approached in any real market. Finally, in the present experiments I have varied the design from one experiment to another in a conscious attempt to study the effect of different conditions of supply and demand, changes in supply or demand, and changes in the rules of market organization on market-price behavior.

between those schedules and what is observed in the market they are presumed to represent. All the supply and demand schedules can do is set broad limits on the behavior of the market.[6] Thus, in the symmetrical supply and demand diagram of Chart 1, it is conceivable that every buyer and seller could make a contract. The \$3.25 buyer could buy from the \$3.25 seller, the \$3.00 buyer could buy from the \$3.00 seller, and so forth, without violating any restrictions on the behavior of buyers and sellers. Indeed, if we separately paired buyers and sellers in this special way, each pair could be expected to make a bilateral contract at the seller's minimum price which would be equal to the buyer's maximum price.

It should be noted that these experiments conform in several important ways to what we know must be true of many kinds of real markets. In a real competitive market such as a commodity or stock exchange, each marketer is likely to be ignorant of the reservation prices at which other buyers and sellers are willing to trade. Furthermore, the only way that a real marketer can obtain knowledge of market conditions is to observe the offers and bids that are tendered, and whether or not they are accepted. These are the public data of the market. A marketer can only know his own attitude, and, from observation, learn something about the objective behavior of others. This is a major feature of these experimental markets. We deliberately avoid placing at the disposal of our subjects any information which would not be practically attainable in a real market. Each experimental market is forced to provide all of its own "history." These markets are also a replica of real markets in that they are composed of a practical number of marketers, say twenty, thirty, or forty. We do not require an indefinitely large number of marketers, which is usually supposed necessary for the existence of "pure" competition.

One important condition operating in our experimental markets is not likely to prevail in real markets. The experimental conditions of supply and demand are held constant over several successive trading periods in order to give any equilibrating mechanisms an opportunity to establish an equilibrium over time. Real markets are likely to be continually subjected to changing conditions of supply and demand. Marshall was well aware of such problems and defined equilibrium as a condition toward which the market would move *if* the forces of supply and demand were to remain stationary for a sufficiently long time. It is this concept of equilibrium that this particular series of experiments is designed, in part, to test. There is nothing to prevent one from passing out new buyer and/or seller cards, representing changed demand and/or supply conditions, at the end of each trading period if the objective is to study the effect of such constantly changing conditions on market behavior.

[6] In fact, these schedules are modified as trading takes place. Whenever a buyer and a seller make a contract and "drop out" of the market, the demand and supply schedules are shifted to the left in a manner depending upon the buyer's and seller's position on the schedules. Hence, the supply and demand functions continually alter as the trading process occurs. It is difficult to imagine a real market process which does not exhibit this characteristic. This means that the intra-trading-period schedules are not independent of the transactions taking place. However, the *initial* schedules prevailing at the opening of each trading period are independent of the transactions, and it is these schedules that I identify with the "theoretical conditions of supply and demand," which the theorist defines independently of actual market prices and quantities. One of the important objectives in these experiments is to determine whether or not these initial schedules have any power to predict the observed behavior of the market.

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