Natural Monopoly and the Contestable Markets Hypothesis: Some Preliminary Results from Laboratory Experiments

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NATURAL MONOPOLY AND CONTESTED MARKETS: SOME EXPERIMENTAL RESULTS*

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I. INTRODUCTION

The concept of natural monopoly is one of the most familiar in economics. Most textbook descriptions are similar to that of Mansfield:

. . . [A] firm may become a monopolist because the average cost of producing the product reaches a minimum at an output rate that is big enough to satisfy the entire market at a price that is profitable. In a situation of this sort, if there is more than one firm producing the product, each must be producing at a higher-than-minimum level of average cost. Each may be inclined to cut the price to increase its output rate and reduce its average costs. The result is likely to be economic warfare—and the survival of a single victor, the monopolist.1

Many supposed natural monopolies are the object of widespread state, local, and federal regulation. It was in addressing issues of public utility regulation that Demsetz laid the foundation for an alternative scenario for decreasing cost markets.2 In a model of rivals offering goods or services through a bidding process, Demsetz says:

Economies of scale in production imply that the bids submitted will offer increasing quantities at lower per unit costs, but production scale economies imply nothing obvious about how competitive these prices will be. If one bidder can do the job at less than two or more, because each would then have a smaller output rate, then the bidder with the lowest bid price for the entire job will be awarded the

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contract, whether the good be cement, electricity, stamp vending machines, or whatever, but the lowest bid price need not be a monopoly price.  

Demsetz’s article promoted a debate over whether a formal auction system might provide a practical approach to monopoly control. This literature is rich in examining the practical difficulties of implementing such an institution. Recent work in the Demsetz tradition is embodied in what has been called the “contestable markets” theory. This literature argues that the forces Demsetz saw as disciplining price in a “natural monopoly” depend only on entry and do not require the implementation of a formal auctioneering mechanism. As Bailey has argued:

[Its [the theory’s] most dramatic results relate to natural monopoly. The theory pertains to markets which have substantial attributes of natural monopoly, but which are characterized by free and easy entry and exit. For such markets, the cost-minimizing market structure calls for a single seller, yet the theory asserts that these sellers are without monopoly power. In the case of contestable markets, potential entry or competition for the market disciplines behavior almost as effectively as would actual competition within the market. Thus, even if operated by a single firm, a market that can be readily contested performs in a competitive fashion.]

In the typical description of the dynamics of natural monopoly theory, the single survivor of price cutting in a scale-economies environment operates as a true monopolist because the survivor gains the protection of alleged barriers to entry. Yet, several of the advocates of contestable markets hypotheses argue that it is not the economies of scale per se that pose an entry barrier. They suggest that only if the cost curves reflect

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3 Id. at 57.

4 See, for exam| Oliver E. Williamson, Franchise Bidding for Natural Monopolies—in General and with respect to CATV, 7 Bell J. Econ. 73 (1976); | Martin Loeb & Wesley A. Magat, A Decentralized Method for Utility Regulation, 22 J. Law & Econ. 399 (1979).


6 A representative example from an undergraduate text is the following quote from James P. Quirk, Intermediate Microeconomics 260 (1st ed. 1976): “Any prospective entrant faces the problem that the monopolist can squeeze him out by lowering price in the short run to the level where the entrant takes losses only to raise the price again to the monopoly level once the entrant has been bankrupted.”
large sunk fixed costs already borne by the incumbent can the incumbent firm even be assumed to be advantaged over potential entrants.\textsuperscript{7}

The important characteristic of the contestable markets hypothesis, as we interpret it, is that at least two firms bid, in the sense of Demsetz, directly for buyer purchases. Note that we do \textit{not} mean that at least two firms bid for the alienable right to supply a particular market as a monopolist. In this latter case, monopoly is cast in the concrete of law, and bidding merely permits the owner of the auctioned right (the city, U.S. Treasury, and so on) to capture all the monopoly rents. Under our bidding interpretation we refer (as does Demsetz) to a free and open right to supply, with the market’s being won by the lowest price bidder. This bidding could occur within a formal auction process or through the unstructured price announcements of firms who are actual or potential rivals.

Much of the research in the area of contestable markets deals explicitly and directly with the applicability of the contestable markets hypothesis to questions of public regulatory policy.\textsuperscript{8} The current economic and political climate suggests that questions relating to the deregulated performance of currently or historically regulated markets are of continuing concern. The acceptability and/or applicability of the contestable markets hypothesis may play an important role in the regulatory future of industries such as trucking, communications, and banking. For example, the chairman of the Interstate Commerce Commission (ICC) is reported to favor a requirement that truckers relinquish any unused operating permits.\textsuperscript{9} The existence of unused permits in any particular market, however, is essential if the market is to be contested with a minimum of regulatory delay. The purpose of our research is to examine both the natural monopoly and the contestable markets hypotheses using appropriately designed laboratory experiments.

In Section IV we report four experiments, each with a single seller (the “monopoly” case), in which the effective cost of entry for a second firm is infinite and six experiments, each with two potential sellers (the “duopoly” case), whose cost of entry is zero. Originally we planned to do

\textsuperscript{7} See, for example, Bailey, \textit{supra} note 5, at 178–79; Bailey & Panzar, \textit{supra} note 5, at 128–29; Baumol & Willig, \textit{supra} note 5, at 418–19. Quirk, \textit{supra} note 6, also makes the point about sunk costs in the second edition of the textbook, at 310.

\textsuperscript{8} Especially Bailey, \textit{supra} note 5; Bailey & Panzar, \textit{supra} note 5; and Baumol, \textit{supra} note 5.

\textsuperscript{9} Business Week, November 9, 1981, reports at 74, “ICC sources say Taylor ordered his aides to draft a position paper advocating that truckers relinquish all operating rights not being used.”
only four duopoly experiments, but the results of two of our first four duopolies (posted offer experiments 37 and 48) were not as unequivocal as the other two (45 and 47). Consequently, we expanded the sample size with two additional duopoly experiments (51 and 52). In all experiments all firms have identical decreasing marginal costs to capacity, and the capacity output of any firm is sufficient to satisfy the entire market demand. The price mechanism employed is a multiperiod posted offer market (explained in the next section), in which sellers quote public offers and buyers privately select the sellers from whom units are purchased. In the duopoly experiments each seller has an equal and unrestricted right to the market with each seller's market share determined by the buyers who are free to choose between the two posted price offers.

One of the principal tasks of the research has been to state correctly and explicitly the predictions of the contestable markets hypothesis in the context of our experimental design. This hypothesis can be interpreted in both "strong" and "weak" forms. It could be interpreted as suggesting that the existence of two identical potential sellers is enough to bring forth competitive price and quantity. Or, in a slightly weaker version applicable to experimental markets, the markets might converge to the competitive outcomes across time. On the other hand, such requirements might be too strong. After all, in the more familiar realm of nondecreasing cost industries, there are innumerable nonmonopoly predictions of duopoly behavior that also differ from purely competitive outcomes. Similar "intermediate" behavior might be observed in a contested decreasing cost duopoly. Thus, both a weak and a strong version of the contestable markets hypothesis will be derived in Section IV.

We next note that the contestable markets hypothesis (in either version) is falsifiable within our experimental design. There are at least two types of observed behavior that would lead to a failure of the hypothesis. First, the duopolists might use the vehicle of price signaling to establish a tacitly coordinated "shared monopoly." In our experimental design there is a strong incentive for such coordination, since the maximum profit to be shared by such a strategy is nearly $94 over twenty-five decision periods. If the duopolists were to "take turns" charging the monopoly price, each would pocket $47. Second, the duopolists may be found to behave in a manner suggested by the earlier reported description of the more traditional natural monopoly arguments. In our design, a seller who serves the entire market may still just break even at a low competitive price with all demand revealed. If sellers post identical prices and split the market, losses may be incurred. Either firm, fearful of such losses in a contested market, could prefer zero profits with certainty by conceding the entire market to the rival. (Of course, nothing in this version of the traditional
alternative to the contestable markets hypothesis predicts which firm will be the ‘‘survivor.’’) If either of these alternate patterns of behavior (a collusive shared monopoly or a surviving monopolist) yields outcomes different from competitive predictions, then the contestable markets hypothesis is falsifiable in our design. This raises an important subsidiary question: What is the single uncontested seller (monopoly) outcome in this decreasing cost design? Comparing the behavior of contested markets only with theoretical monopoly predictions could be misleading. It is not self-evident that a single seller or collusive sellers facing unknown demand and profit motivated buyers will in fact be able to achieve the theoretical monopoly outcomes. If the results of the duopoly experiments are significantly different from theoretical monopoly predictions, this might be caused not by the contesting of the market but rather by some other feature of this cost and demand environment, such as a strategic decision by one or more buyers to underreveal demand.

The four true monopoly experiments (34–36, 46), in which it is common knowledge that there is only one actual or potential seller, serve as the monopoly behavior standard for comparison with the contested duopoly results. It might be thought that the results of a monopoly experiment would be trivially unsurprising with price and output converging quickly to the monopoly equilibrium. Such an assumption confuses the condition of monopoly (one uncontested seller) with monopoly behavior. Actual monopolists, like our experimental monopolists, do not know their demand functions except as demand is revealed at quoted prices by the free choice of buyers. Monopoly theory assumes implicitly that all buyers reveal 100 percent of their demand and that the seller optimally restricts supply. Smith reports the results of nine increasing-cost monopoly experiments (using five buyers) conducted under the double auction, offer auction, posted bid, and posted offer pricing institutions. The one posted offer experiment that was reported converged quickly to the monopoly equilibrium with no buyer’s withholding demand. In all the other institutions, prices and allocations failed to achieve monopoly levels and in many cases converged to levels near the competitive equilibrium because of successful buyer signaling and underrevelation of demand. This suggests that the posted offer institution is more likely than the other institutions to achieve a monopoly equilibrium, but such a generalization from

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the result of one experiment is not justified. Even if the reported result is replicable, we do not know whether it extends to the decreasing-cost case. Hence, the need for a rigorous empirical test of the single-seller monopoly hypothesis which could be falsified by persistent strategic underrevelation of demand by buyers, or a failure of the seller to price optimally, or some other unanticipated feature of this design.

Table 1 lists all possible outcome combinations in each of the two (monopoly, duopoly) market types on the assumptions that a (price, quantity) observation is counted as supporting either the theoretical monopoly or competitive predictions. For example, an outcome (price or quantity) might be counted as “competitive” support if it is closer to the competitive than monopoly predictions. (Notice that this implies that, for purposes of this table, we have ignored the distinction between the strong and weak forms of the contestable markets hypothesis.) Of the four price-quantity, monopoly-competitive combinations in each of the two market types, one (competitive quantity/monopoly price) is impossible. A necessary condition for confirming (that is, nonfalsifying) either the standard monopoly theory (in the single seller design) or the contestable markets hypothesis (in the duopoly design) is that demand be fully revealed. The standard monopoly result requires supply restriction by the single seller, while the contestable markets hypothesis requires that at least one duopolist fully serve the market at the competitive price.

II. The plato Posted Offer Procedure

Most retail markets are organized under what has been called the posted offer institution.\(^{11}\) As we define it, in this institution each seller independently posts a take-it-or-leave-it price at which deliveries will be made in quantities elected by each individual buyer subject to seller capacity limits. These posted prices may be changed or reviewed frequently, infrequently, regularly, or irregularly, but in any case a central characteristic of this mechanism is that the posted price is not subject to negotiation.

The experiments reported here use the posted offer mechanism programmed for the plato computer system by Jonathan Ketcham.\(^{12}\) This program allows subject buyers and sellers, sitting separately at plato terminals, to trade for a maximum of twenty-five market “days” or pric-

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### TABLE 1
A Classification of Alternative Experimental Outcomes and Possible Types of Behavior

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Outcome</th>
<th>Possible Behavior</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Monopoly</td>
<td>M1</td>
<td>Mp, Mq</td>
<td>B: Demand fully revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply optimally restricted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not falsify traditional monopoly theory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>Cp, Mq</td>
<td>B: Demand under revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply unrestricted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falsifies traditional monopoly theory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>Cp, Cq</td>
<td>B: Demand revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply unrestricted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falsifies traditional monopoly theory</td>
<td></td>
</tr>
<tr>
<td>Contestable Markets Hypothesis Duopoly</td>
<td>C1</td>
<td>Mp, Mq</td>
<td>B: Demand fully revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply optimally restricted by either</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>i) tacit collusion of 2 firms, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ii) a &quot;surviving&quot; monopolist is ceded the market</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falsifies CMH, a &quot;Natural Monopoly&quot; type of outcome</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>Cp, Mq</td>
<td>B: Demand under revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply restricted by either</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>i) tacit collusion of 2 firms, or</td>
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<td>ii) a &quot;surviving&quot; monopolist is ceded the market</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falsifies CMH</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>Cp, Cq</td>
<td>B: Demand revealed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S: Supply unrestricted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not falsify CMH</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE.** \(-M_p: \) Price supports theoretical monopoly prediction; \(M_q: \) Quantity supports theoretical monopoly prediction; \(C_p: \) Price supports theoretical competitive prediction; \(C_q: \) Quantity supports theoretical competitive prediction; \(B: \) Buyers; \(S: \) Seller(s); CMH: Contestable markets hypothesis.

...ing periods. The display screen for each subject shows his or her record sheet, which lists a maximum of five units that can be purchased (sold) in each period. For each unit, the buyer (seller) has a marginal valuation (cost) which represents the value (cost) to him or her of purchasing (selling) that unit. These controlled, strictly private unit valuations (costs) induce individual, and aggregate market, theoretical supply and demand...
schedules. That is, in an experiment, buyers (sellers) earn cash rewards equal to the difference between the marginal value (selling price) of a unit and its purchase price (marginal cost). Sales are “to order” in the sense that there are no penalties, or carry-over inventories, associated with units not sold (or units not purchased). Consequently the assigned marginal valuations and costs induce well-defined flow supply and demand conditions.

Each period begins with a request that sellers select a price offer by typing a price into the computer keyset. This offer is displayed privately on the seller’s screen. The seller is then asked to select a corresponding quantity to be made available at that offer price. The maximum number of units a seller can offer corresponds to the number of the last unit whose cost is not greater than the offer price. The minimum number of units a seller can offer corresponds to the number of the first unit whose cost is not greater than the offer price. (However, the seller is required to offer at least one unit; that is, a seller cannot post a price for zero units.) This procedure permits individual-induced marginal costs to be declining, constant, or increasing. If the seller faces declining marginal costs, as in the experiments reported below, these minimum and maximum quantity constraints prevent his choices from being such that a loss is guaranteed, but if price is below the first unit marginal cost, a loss will be taken on the first units sold that must be more than offset by profits on later units if an overall profit is to be earned in the period. Since it is costly in time and effort for a seller to calculate the profit that any given offer may provide, especially with declining costs, PLATO always informs the seller of the potential profit (loss) if all offered units are sold. When a seller is satisfied with the selected price and quantity, he presses a touch sensitive “offer box” displayed on the screen. This action places, irrevocably, that seller’s offer in the market. Before touching the offer box the seller may change the price and/or quantity as many times as desired. Each seller learns his competitor’s price, in the current period, only after each has entered his price into the market.

The screen viewed by the buyer displays one price box for accepting units offered by each seller. After all sellers have entered their offers, each seller’s price is posted in these buyers’ acceptance boxes and at the bottom of each seller’s screen. PLATO then randomly orders the buyers in a buying sequence, and the first is informed that he may now purchase the good. A buyer, once selected, can purchase from any seller. To purchase a unit from a selected seller, the buyer presses the box corresponding to

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that seller, then depresses a "confirm" key on the keyset. Repeating this sequence causes a second unit to be purchased, and so on. A buyer is allowed to purchase up to his buying capacity from any seller or sellers. However, a buyer can neither purchase a unit whose price is greater than the unit’s marginal valuation nor buy from a seller who has sold all of the units offered. When a seller’s last available unit is sold the price appearing in the buyer’s box for that seller is replaced with the message “out of stock” on the buyer’s screen. After the first buyer has finished making purchases, the next buyer in random order may begin purchasing, and so on. The period ends when the last buyer completes this buying mode and price posting for the next period begins.

Thus, the posted offer mechanism captures the essential feature of the Bailey and Panzar models in that the actual allocation of sales to firms is made by the buyers themselves and not by an auctioneer or regulatory intermediary.

It is important to emphasize that buyers and sellers have only limited information. All unit values (costs) assigned to individual buyers (sellers) are strictly private, known only to the subject (and the experimenter). Each buyer sees all of the seller’s price offers but not the quantities available at these prices. In the experiments reported below sellers do not see the price posted by other sellers in the current period until after each has entered his own final price selection for that period. Finally, buyers (sellers) know only their own purchases (sales) and profits. Nevertheless, something less than a perfectly noncooperative setting exists. With each seller seeing the prices posted by other sellers in all previous periods, some indirect communication (or "price signaling") can be attempted. Such signaling has been observed in previous posted offer markets but has not proven to be very successful in effecting collusion.14

### III. Experimental Design

We report ten experiments—four with a single seller and six with two sellers. The duopoly sellers are each given marginal cost schedules identical with the schedules given to the monopoly sellers (except perhaps for a parameter-disguising constant added to all unit costs and values). The aggregate demand and individual marginal cost schedules are shown on the left of Figure 1. We define the competitive equilibrium quantity, $Q_c$, as the largest quantity that can be sold without loss by at least one seller (that is, where average cost is less than or equal to price, or $AC(Q_c) \leq D(Q_c)$). Since demand is sufficient to satisfy no more than one seller at

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14 See Ketcham, Smith, & Williams, supra note 12.
PER-PERIOD RESULTS ON PRICE AND QUANTITY

(ALL EXPERIMENTS)

4. SINGLE-SELLER EXPERIMENTS
(P034, P035, P036, P046)

6. CONTESTED DUOPOLY EXPERIMENTS
(P037, P041, P047, P051, P052)

P: Price Range
Pc: Competitive Price Range
Qc: Competitive Quantity
Qm: Monopoly Quantity
Qm: Lower Monopoly Quantity
Po: Market Price
A: All prices measured in deviations from AC(0.)

TWO SELLERS

$1.41

FIGURE 1

All prices measured in deviations from AC(0.)

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capacity sales, $Q_c = 10$, whether there is one seller or two. Any price which supports $Q_c$ is a competitive equilibrium price. In our experimental design any $P_e \in [AC(10), AC(10) + .12]$ is a competitive equilibrium price. The individual unit marginal valuations, marginal costs, and average costs are shown in Table 2, measured in deviations from AC(10).

All five buyers in each experiment had participated in at least one previous posted offer experiment, but with design parameters different from the experiments reported here. Since the PLATO posted offer mechanism provides for a maximum trading capacity of five units for each agent (a screen display limitation) each monopoly experiment was initialized as if there were “two” sellers (each duopoly as if there were “four” sellers). Then each subject seller was provided two adjacent terminals. The fact that the markets actually consisted of one or two sellers (not two or four) was known to all participants.

Some of the parameter implications of this design for both monopoly and duopoly are summarized in Table 3.\(^{15}\) Note that if a firm posts the monopoly price, and if it is the only firm or this is the lowest price, then the seller makes a profit of $3.75 in the period. Each seller has an incentive to post a lower price if he thinks the other seller will post any given price above $P = 0$. If the two sellers post the same price, one of the two sellers may incur a loss depending on how buyers choose to divide their purchases. If buyers are egalitarian and divide their purchases equally, then both sellers incur losses at tied prices below $\$0.75$. Because of the scale economies, there is a social loss if either firm satisfies less than 100 percent of the demand at any ruling price.

It is worth reemphasizing at this point the methodological approach of this design. We have attempted to insure that the duopoly markets exhibit as few potential barriers to entry or competition as possible, except for those that derive from the natural monopoly nature of the cost functions of the two sellers. Bailey and Panzar report on their theory as follows:

\(^{15}\) The use of two PLATO terminals required us to alter their parameters slightly under certain unusual conditions. The sellers’ profits in each of the periods consisted of the sum of the profits on the first five units (left terminal) and on the next five units (right terminal). This addition was done by hand and not internally in PLATO. Because of the decreasing costs, sellers typically lost money on some early units and made money on the later ones. By a coincidence of the experimental design, prices at or below the upper bound of the competitive price range guaranteed a loss on the first five units, tripping the internal filter in the PLATO program designed to keep persons from guaranteeing themselves a monetary loss in the period. To correct this, we lowered the cost of the fifth unit by 25 cents if and only if a seller attempted to enter a price in the competitive price range. This intramarginal change in rent had only one effect on the parameters or predictions of the model; by lowering average cost, it dropped the lower bound of the competitive price range by 2.5 cents for persons trading in that range. The upper competitive price, the competitive quantity, and the monopoly price and quantity predictions were unchanged.
### Table 2

**Induced Individual Values and Costs**

<table>
<thead>
<tr>
<th>Agent</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer 1</td>
<td>2.37</td>
<td>.12</td>
<td>-.88</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>.</td>
</tr>
<tr>
<td>Buyer 2</td>
<td>2.12</td>
<td>.37</td>
<td>-.13</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>.</td>
</tr>
<tr>
<td>Buyer 3</td>
<td>1.87</td>
<td>.62</td>
<td>-.63</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>.</td>
</tr>
<tr>
<td>Buyer 4</td>
<td>1.62</td>
<td>.87</td>
<td>-.38</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>.</td>
</tr>
<tr>
<td>Buyer 5</td>
<td>1.37</td>
<td>1.12</td>
<td>-1.13</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>. .</td>
<td>.</td>
</tr>
<tr>
<td>Seller 1</td>
<td>1.12</td>
<td>.87</td>
<td>.62</td>
<td>.37</td>
<td>.12</td>
<td>-.13</td>
<td>-.38</td>
<td>-.63</td>
<td>-.88</td>
<td>-1.13</td>
</tr>
<tr>
<td>Average</td>
<td>1.12</td>
<td>1.00</td>
<td>.87</td>
<td>.75</td>
<td>.62</td>
<td>.50</td>
<td>.37</td>
<td>.25</td>
<td>.12</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note.** All values and costs are stated in deviations from AC(10).
**TABLE 3**

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of buyers</td>
<td>5</td>
</tr>
<tr>
<td>Monopoly price (normalized)</td>
<td>1.12</td>
</tr>
<tr>
<td>Seller surplus (per period) at $P = 1.12$</td>
<td>3.75</td>
</tr>
<tr>
<td>Buyer surplus (per period) at $P = 1.12$</td>
<td>3.75</td>
</tr>
<tr>
<td>Competitive price (normalized)</td>
<td>[0,.12]</td>
</tr>
<tr>
<td>Seller surplus (per period) at $P = 0$</td>
<td>0</td>
</tr>
<tr>
<td>Buyer surplus (per period) at $P = 0$</td>
<td>12.50</td>
</tr>
</tbody>
</table>

"The theory of contestable markets has been developed to analyze the equilibrium properties of markets that may have economies of scale but that are characterized by perfectly free and easy entry and exit."\(^{16}\) In testing this theory, we have attempted to reproduce these conditions specified by the theory. If the theory is falsified, we are done; that is, no further experiments are necessary. If the theory is not falsified, a wide range of questions opens about the robustness of the assumptions behind the contestable markets hypothesis. This would call for further study by theoretical, empirical, and experimental economists into the limits of contesting as a discipline against monopoly behavior.

**IV. Hypotheses and Experimental Results**

The contestable markets hypotheses presented in the introduction can be formalized in a manner conducive to laboratory experimentation. Define a vector $(P, Q, E)$ as price, quantity, and market efficiency. The theoretical competitive equilibrium predictions, $(P_c, Q_c, E_c)$, and the theoretical monopoly equilibrium predictions, $(P_m, Q_m, E_m)$, are constant vectors given by economic theory. From the actual laboratory experiments come vectors describing laboratory monopolies, $(P_s, Q_s, E_s)$, and duopolies $(P_d, Q_d, E_d)$. These results could and did vary over the course of the experiments.

We define a laboratory strong version of the contestable markets hypothesis in terms of convergence of the duopoly results over time to the competitive predictions:

$$H_s: (P_d, Q_d, E_d) \rightarrow (P_c, Q_c, E_c)$$

$$\tilde{H}_s: (P_d, Q_d, E_d) \not\rightarrow (P_c, Q_c, E_c).$$

\(^{16}\) Bailey & Panzar, *supra* note 5, at 125.
There is also a weak interpretation of the contestable markets hypothesis. The laboratory duopolies could exhibit neither monopoly nor competitive behavior, but some intermediate outcome. While the market is not a true “closed” monopoly, the two sellers may each have some market power that is not eliminated by the contestability of the market. The following is a formal statement of a weak version of the contestable markets hypothesis:

\[
H_w: \ P_d \leq \frac{P_m + P_c}{2} \\
Q_d \geq \frac{P_m + P_c}{2} \\
E_d \geq \frac{E_m + E_c}{2}
\]

versus

\[
\hat{H}_w: \ P_d > \frac{P_m + P_c}{2} \\
Q_d < \frac{Q_m + Q_c}{2} \\
E_d < \frac{E_m + E_c}{2}
\]

That is, if the weak version of the competitive markets hypothesis fails, then the duopolies will be achieving outcomes closer to the monopoly than to the competitive predictions. Such behavior could be manifested by a single monopoly survivor, by a shared monopoly, or by some kind of rotating monopoly behavior.

On the other hand, a monopolist may not be able to exercise complete monopoly power within a market. It is important to separate competitive pressure due to factors of contestability from any underlying weakness with respect to the applicability of theoretical monopoly predictions. Therefore, we next define an ordering hypothesis that requires that laboratory contestable duopoly markets actually perform more competitively than laboratory monopolies:

\[
H_0: \ P_d \leq \frac{P_s + P_c}{2} \\
Q_d \geq \frac{Q_s + Q_c}{2} \\
E_d \geq \frac{E_s + E_c}{2}
\]
versus

\[ \hat{H}_0:\ P_d > \frac{P_s + P_c}{2} \]

\[ Q_d < \frac{Q_s + Q_c}{2} \]

\[ E_d \leq \frac{E_d + E_c}{2}. \]

Figure 1 charts the lowest ruling price and the quantity traded in each period for the ten experiments.\(^\text{17}\) Figure 2 charts the mean monopoly and mean duopoly prices computed for all experiments in each treatment. Table 4 summarizes the mean price, quantity, efficiency, and the index of monopoly effectiveness (the proportion of theoretical monopoly profit actually realized by the seller(s)).\(^\text{18}\)

The most striking feature of these results is the overwhelming support they give at least to the weak version of the contestable markets hypothesis. Mean duopoly price is closer to the competitive price than the

\(^{17}\) In 46, the monopolist entered a price in trading period 20 that he later said was accidentally and incorrectly $1.00 lower than he wanted.

\(^{18}\) Complete copies of the data protocols for all experiments are available from the authors.
<table>
<thead>
<tr>
<th>Period</th>
<th>Mean Quantity, Monopoly</th>
<th>Mean Quantity, Duopoly</th>
<th>Mean Efficiency Monopoly</th>
<th>Mean Efficiency Duopoly</th>
<th>Mean Monopoly Effectiveness Monopoly</th>
<th>Mean Monopoly Effectiveness Duopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.50</td>
<td>7.70</td>
<td>44.67</td>
<td>76.67</td>
<td>.42</td>
<td>.53</td>
</tr>
<tr>
<td>2</td>
<td>5.00</td>
<td>7.70</td>
<td>46.00</td>
<td>76.67</td>
<td>.57</td>
<td>.53</td>
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<td>3</td>
<td>5.75</td>
<td>8.20</td>
<td>57.50</td>
<td>81.67</td>
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<td>.51</td>
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<td>4</td>
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<td>7.80</td>
<td>58.00</td>
<td>75.50</td>
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<td>.36</td>
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<td>7.80</td>
<td>60.50</td>
<td>76.00</td>
<td>.64</td>
<td>.39</td>
</tr>
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<td>6</td>
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<td>8.20</td>
<td>67.50</td>
<td>79.30</td>
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<td>.43</td>
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<td>7</td>
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<td>83.80</td>
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<td>61.50</td>
<td>88.70</td>
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<td>.36</td>
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<tr>
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<td>6.25</td>
<td>9.30</td>
<td>61.00</td>
<td>90.30</td>
<td>.57</td>
<td>.35</td>
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<tr>
<td>13</td>
<td>6.75</td>
<td>9.20</td>
<td>65.50</td>
<td>85.50</td>
<td>.59</td>
<td>.34</td>
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<td>14</td>
<td>6.75</td>
<td>9.30</td>
<td>66.50</td>
<td>76.90</td>
<td>.56</td>
<td>-.14</td>
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<td>15</td>
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<td>9.20</td>
<td>56.00</td>
<td>86.50</td>
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<td>.10</td>
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<td>16</td>
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<td>81.20</td>
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<td>-.06</td>
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<td>9.30</td>
<td>49.00</td>
<td>85.50</td>
<td>.56</td>
<td>.02</td>
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<td>10.00</td>
<td>60.00</td>
<td>100.00</td>
<td>1.00</td>
<td>(0 to .3625)</td>
</tr>
</tbody>
</table>
monopoly price at period 1 and tends to decay thereafter. Mean duopoly quantity follows a similar pattern after period 5. Only in efficiency are the results not so clear cut. Mean duopoly efficiency is never as low as 60 percent, and in nine of the final ten periods it is closer to the competitive than monopoly level. The efficiency time path is more erratic than the quantity dimension because of several ties in pricing in which both firms supply the market at inefficiently low output levels.

In period 18, the last period for which data are available for all experiments, the market performance vectors are as follows:  

<table>
<thead>
<tr>
<th></th>
<th>Duopoly Mean</th>
<th>Monopoly Mean</th>
<th>Competitive Theory</th>
<th>Monopoly Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>.182</td>
<td>1.0425</td>
<td>(0, .12)</td>
<td>(1.12 or 1.37)</td>
</tr>
<tr>
<td>Quantity</td>
<td>9.3</td>
<td>5.00</td>
<td>10.0</td>
<td>(6.0 or 5.0)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>85.5</td>
<td>49.00</td>
<td>100.0</td>
<td>(60.0 or 50.00)</td>
</tr>
</tbody>
</table>

The data are almost, but not quite, as convincing with regard to the strong version of the contestable market hypothesis. We state this reservation primarily because of the bifurcated nature of the data (see Figure 1). Four duopoly experiments had price and quantity outcome that converged directly to the competitive predictions. For these, the strong version of the hypothesis clearly holds. The other two duopoly experiments never achieved the competitive outcomes, although a visual inspection suggests they were tending in that direction. To test whether these experiments actually demonstrated convergent tendencies, we estimated the following regressions:

$$\ln P_t = A_0 + A_1 t + U_t,$$

where \( P_t \) was the normalized price above the top of the competitive set in period \( t \); \( A_0 \), and \( A_1 \) are coefficients, \( A_1 \) being a decay parameter; and \( U_t \) is the error term. Ordinary least squares on the twenty-five observations of both experiment 37 and experiment 48 yielded the following results (\( t \)-statistics in parentheses), for 37:

$$\ln P_t = -0.3813 - 0.0258 t;$$

\((-8.08)\) \((-8.14)\)

---

Dan Alger of the FTC pointed out to us after work on this research had begun that there are actually two points at which monopoly profits obtained. One, the lower of the two, is the one we had designated as \( P_m \). The other is at \( P_m + .25 \), which may explain the tendency of two of the monopoly experiments to evince several periods of pricing near this point.
for 48:

\[ \ln P_t = -0.58 - 0.025 t; \]
\[ (-7.54) \quad (-4.88) \]

(48 adjusted for autocorrelation):

\[ \ln P_t = -0.5836 - 0.0240 t. \]
\[ (-4.55) \quad (-2.85) \]

The negative coefficient on the time variable (with significant \( t \)-statistic) in each equation suggests that price in these two experiments decayed toward the competitive range at the rate of about 2.5 percent per period, thus supporting the laboratory-markets version of the strong contestable markets hypothesis.

It is necessary to examine these results, which support the competitive markets hypothesis, in the light of the behavior of true single-seller markets. The importance of this comparison is in seeing whether our conclusions of competitive behavior stand when actual monopoly behavior is used as the benchmark. Again, the data are clear cut. Qualitatively, it can be seen that the mean duopoly price is more competitive than the mean monopoly price in eighteen out of eighteen periods; mean duopoly quantity is greater in eighteen of eighteen periods, and mean duopoly efficiency is greater in eighteen of eighteen periods.

Two nonparametric tests were used to judge the robustness of the qualitative observation that contested duopolies are more competitive than the laboratory monopolies. First, a binomial cell test over the two intervals

\[ I_1: \left( P > \frac{P_m + \bar{P}_c}{2} \right) \]

and

\[ I_2: \left( P < \frac{P_m + \bar{P}_c}{2} \right), \]

where \( \bar{P}_c \) is .12, the maximum of the competitive price range). All four period 18 monopoly prices fell in \( I_1 \) and all six duopoly prices fell in \( I_2 \). This would occur with a probability of .00098 if generated from a random binomial process. Second, a nonparametric Mann and Whitney rank-sum test was conducted.\(^{20} \) This test checks the equality of the distribution of prices between the duopoly and monopoly experiments. A total of eigh-

teen observation periods in each of the ten experiments yielded a sample of 180 observations. Using this sample, the hypothesis that the experimental duopoly prices and experimental monopoly prices arise from different distributions can be accepted at the 99.99995 confidence level. In summary, the use of the observed monopoly data as a benchmark does not alter the conclusion that contestable decreasing-cost duopoly markets behave more competitively than uncontested monopoly counterparts.

Parenthetically, these competitive results occurred in spite of what might be viewed as attempts to keep prices high by means of indirect price signaling. Across the six duopoly experiments, 47 percent of all posted offers were higher than the prevailing market price in the immediately previous market period. But in only 35 percent of these signaling attempts did the signaler’s competitor follow through with a next-period offer price above the signaler’s price.21 This was the anatomy of the failure of signals to yield tacit collusion.

These experiments provided a related set of observations that proved to be very interesting. Even though contested duopolies are clearly different from the single seller counterparts, these laboratory monopolists did not automatically lock on the monopoly outcomes. Experiments 34 and 35 are particularly notable in this regard (see Figure 1). We observed that a principal problem facing the monopolists was the withholding of demand by buyers. Given the decreasing-cost schedule of our monopolists, withholding of demand hits the seller at his most profitable units. Small amounts of withholding resulted in very large reductions in sellers’ profits. Buyer withholding occurred at a much higher rate in the monopoly experiments than in the duopoly experiments (9.14 percent versus

21 The following table provides these data for each experiment:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Incidence of Price Signals (A)</th>
<th>Incidence of Signal Reinforcement (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>9/26 = .346</td>
<td>3/9 = .33</td>
</tr>
<tr>
<td>48</td>
<td>25/48 = .521</td>
<td>8/25 = .32</td>
</tr>
<tr>
<td>47</td>
<td>12/34 = .353</td>
<td>4/12 = .33</td>
</tr>
<tr>
<td>51</td>
<td>20/38 = .526</td>
<td>8/20 = .40</td>
</tr>
<tr>
<td>52</td>
<td>16/34 = .471</td>
<td>8/16 = .50</td>
</tr>
<tr>
<td>All</td>
<td>107/228 = .469</td>
<td>37/107 = .35</td>
</tr>
</tbody>
</table>

Column A: Fraction of price offers by a seller which exceed the previous period’s ruling price and are potentially profitable (signal). Column B: Fraction of “signals” in column A for which the signaler’s competitor followed through in the subsequent period with an offer price above that of the signaler’s price (signal reinforcement).
This tended to discipline the monopolists against attempts to increase price. This discipline appeared to weaken in three of the four experiments as the experiment progressed beyond about fifteen periods (see Figure 1). These withholding effects have important applications in addressing the question, "How tough is it to be a monopolist?" Witness the following case of two segmented air-frame markets, one a contested duopoly, the other apparently serviced by only a single seller:

Delta and other airlines, it's known, had been pushing McDonnell Douglas to build a new plane, if only to spur price competition with Boeing. Until yesterday's announcement, just 52 of the narrow-body 757s had been purchased, as airlines held off to see whether Douglas would enter the fray. The plane Douglas has been considering is known as the DCXX, or ATMR, for Advanced Transport-Medium Range, and would compete directly with the 757.

Meanwhile, Boeing's wide-body 767, which has competition in the form of the European Airbus Industrie A-310, has drawn orders for a healthy 161 aircraft. "Airlines know they get the best deal when two companies are aggressively going after their business," one industry source says.

Apparently, as in our laboratory markets, buyers displayed a greater tendency to withhold demand in the monopoly market than in the duopoly market.

V. CONCLUSIONS, INTERPRETATIONS, AND IMPLICATIONS

The most significant conclusion of this research is that the behavioral predictions of the contestable market hypothesis are fundamentally correct. It is simply not true that monopoly pricing is a "natural" result of a market merely because firms in the market exhibit decreasing costs and demand is sufficient to support no more than a single firm.

The data from these experiments point toward an even stronger conclusion. There is clear evidence not only that contesting duopolies exhibit behavior more competitive than theoretical monopoly predictions, but also that they actually perform up to the standards of the competitive

22 These data include all subjects in all six duopoly experiments with the exception of the final one, 52. In that experiment, a single buyer who showed no unusual buying behavior nevertheless was causing the experiment severe problems because of his tendency to play with the PLATO terminal keys in nonprescribed ways. He was excused (in period 3, after the market had already entered the competitive range) and replaced with a graduate student. The replacement was instructed to refrain from withholding demand. Such behavior makes a buyer essentially a passive participant and was virtually the universal pattern observed among buyers in the first five duopoly experiments (in which only 1.16 percent of all demand was withheld). However, because this replacement was so instructed, the data reported include only the other four buyers from experiment 52.

model. Four of our six experiments moved rapidly to competitive outcomes; two others moved in that direction but never actually entered the competitive range. The fact that these results obtained with only two sellers is particularly convincing, since the most familiar paradigm suggests that adding more sellers (if it had any effect at all) would increase the competitive discipline of the marketplace.

As we view it, the essential feature of a contested market is that firms bid directly for the purchases of buyers. If either of two sellers can satisfy the entire market, then the posted offer pricing institution reduces, in its essential features, to a sealed-bid auction in which the seller with the ruling bid collects a price equal to his bid for the entire market.24 Thus, given the market structure, sellers are bidding to supply a single unit, the market, as in a sealed-bid auction with two bidders competing for a single item. However, in this case the item won has a volume dimension that varies with the level of the ruling price. Also, in this case, the tie-breaking rule is discretionary, since it depends on the free choice made by each buyer. The usual tie-breaking rule in sealed-bid auctions is to make the award to one of the bidders at random (an equally likely choice). Note that such a rule is more efficient than the “buyer’s discretion” rule in posted offer markets, since the random award rule guarantees the market to one seller. With increasing returns it is always better to have all sales made by one seller.

The sealed-bid interpretation also provides a possible explanation of different modes of contested market behavior. As shown by Cox, Roberson, and Smith, risk-averse buyers will bid more (sellers will bid less) than risk-neutral buyers (sellers) for an item sold (purchased) under the high (low) bid rule.25 Hence, greater risk aversion may account for the four contesting duopoly experiments that converged quickly to the competitive equilibrium.

The comparison of our monopoly experiments with our contested market experiments suggests that the contesting of the markets (and not some other feature of our design) was responsible for the competitive tendencies in the latter. An examination of the monopoly experiment is particularly important since our experiments incorporated a finite number of human buyers. This could leave open the possibility that the competitive discipline of the markets is due not directly to contesting by sellers but rather to the actual (or merely anticipated) strategic withholding of de-

24 This analogy was pointed out in Plott & Smith, supra note 11.
mand by buyers. The data presented here suggest that this is not the case. With a 9.14 percent buyer withholding of demand, the monopolists encountered some difficulty in obtaining prices at or near the monopoly level, primarily in the earlier periods. However, by the later periods of the experiment, average monopoly price was close to the predictions of the monopoly model. If this 9.14 percent rate of underrevelation did not ultimately prevent monopolists from obtaining prices at or near a monopoly level, it suggests that it is unlikely that there was any significant effect from the much lower rate of underrevelation (1.16 percent) that occurred in the contested duopolies.

Our research program on contestable markets will expand on the present study by (a) introducing finite nonzero entry costs, and (b) running some experiments in which “dummy” buyers are computer programmed to reveal demand, with this “full revelation” being known by sellers. The results of the present study indicate that experiments under a are needed to explore the entry cost limits of the contestable markets hypothesis. Experiments under b will allow us to examine further our current claim that the competitive tendencies in our duopoly experiments are indeed caused by sellers contesting the market.

26 We wish to thank our referee for emphasizing that the contestable markets theory assumes a “large number” of buyers.