Markets with Posted Prices: Recent Results from the Laboratory

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Abstract

The general perception that laboratory markets yield efficient competitive outcomes seems to contradict the emphasis on market imperfections that pervades much of the theoretical work in industrial organization. This apparent contradiction is resolved by considering the effects of trading institutions: Competitive outcomes are indeed typical in laboratory markets where trading follows the "double auction" rules similar to those used in many centralized financial exchanges. But most markets of interest to industrial organization economists have a very different institutional structure; sellers post prices, and buyers must either make a purchase on the terms proposed by the seller, or engage in costly search and negotiation to obtain discounts. Unlike more competitive double auctions, the performance of markets with posted prices can be seriously impeded by the presence of market power, price-fixing conspiracies, and cyclical demand shocks. This paper reviews our research on performance in posted-price markets with such imperfections.

I. Introduction

In many markets, it is common for prices to be set by the traders on the thin side of the market. Sellers, for example, typically post prices in retail markets. For this reason, theoretical (Bertrand) models are often structured around an assumption that prices are listed simultaneously at the beginning of each "period." Using laboratory experiments, it is possible to make controlled comparisons between markets with posted prices and more symmetric institutions such as the "double auction," where both buyers and sellers post bids and asks in an interactive setting that resembles a centralized stock market. Laboratory double auctions yield efficient, competitive

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outcomes in a surprisingly wide variety of settings, sometimes even in a monopoly.[1] Although markets with posted prices do not track competitive predictions as well, the traditional view was that resulting inefficiencies were only part of the price convergence process, and diminished as prices adjusted toward competitive levels. The primary difference between posted-offer and double auction markets was thought to be that in the former, a higher share of the surplus went to traders on the posting side of the market.[2]

This traditional view is contradicted by our recent research and by the related research of others.[3] Posted-price markets respond sluggishly to demand shocks and can yield consistent supra-competitive prices when sellers possess market power. Price-fixing conspiracies are much more pernicious when subjects post prices on a take-it-or-leave-it basis. More recent experiments relax some of the standard assumptions of the Bertrand model, by introducing costly search and the possibility of buyer-specific discounts. These experiments document some interesting anomalies and rigidities that have major implications for new theoretical work in industrial organization and macroeconomics.

The purpose of this paper is to investigate the effects of these sorts of variations on market performance. As a prior matter, however, it is necessary to discuss how laboratory markets are created, and to review some of the empirical regularities that have been observed.

II. Trading Institutions and Market Performance

A market experiment normally consists of a series of trading periods. At the start of each period, sellers are given a capacity, i.e., a listing of units and the corresponding unit costs. The

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[1] This literature is surveyed in Davis and Holt (1993e, chapter 3).

[2] Smith (1982b, p. 951) concludes: "If sellers post offers convergence is from above the C.E. price." In the first major survey of experimental work on industrial organization issues, Plott (1982) summarizes: "Two generalizations seem possible at this time. First, posted-offer (bid) markets tend to have higher (lower) prices than do oral double auction markets in that the adjustment to equilibrium tends to be from above (below) and either converges to equilibrium more slowly or does not converge at all." This statement is qualified in the Plott (1989) update of this survey: "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."

[3] As noted below, some of the contradictions are provided by the work of Vernon Smith and Charles Plott, who are quoted in the previous footnote.

cost is only incurred if the unit is sold, in which case the seller earns the difference between the sale price and the cost. For example, a seller identified as S1 could be given a capacity of 2 units, a first unit with a cost of $1.30, and a second with a cost of $1.40. This seller would then be willing to sell 0 units at a price below $1.30, 1 unit at a price between $1.30 and $1.40, and 2 units at any prices above $1.40. Thus, S1's supply function would have "steps" at $1.30 and $1.40.

Just as sellers are given the capacity to produce at specified costs, buyers are given the capacity to purchase a number of units with specified monetary values, contingent on purchase. A buyer B1, for instance, could have 2 units with values of $1.40, with the understanding that the buyer earns the difference between the value of each unit purchased and the price paid. This would yield a "rectangular" demand function with a step at $1.40. Earnings are calculated in each period, and accumulated earnings are paid in cash at the end of the market session. The value and cost structures for all traders determine the aggregate supply and demand functions, and hence, the theoretical competitive equilibrium price. For example, the supply and demand curves in figure 1 are constructed by aggregating the values and costs for six buyers and six sellers; this structure results in a range of competitive prices from $1.30 to $1.40.

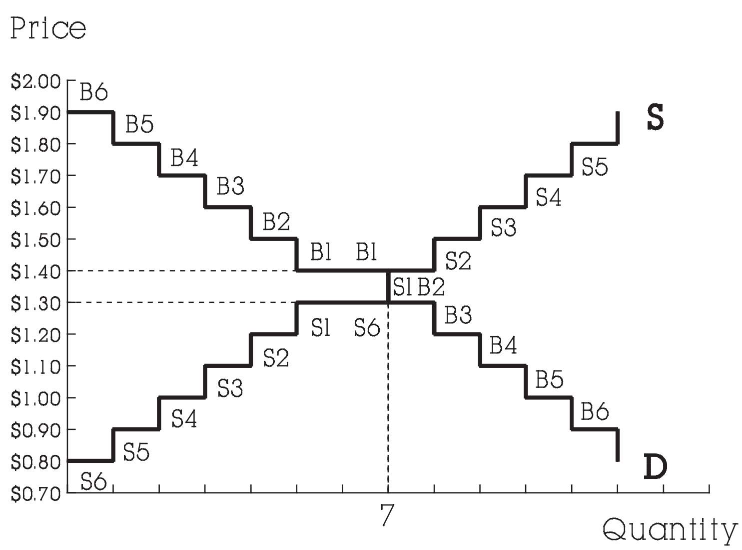

Figure 1. Supply and Demand Structure for a Market Experiment

Most market experiments involve comparisons of market performance under two or more treatments that may, for example, correspond to alternative trading rules or antitrust policies. When the treatments use the same supply and demand structure, it is natural to consider which treatment yields more gains from trade. Just as the individual buyer's values and seller's costs determine the aggregate demand and supply functions, they also determine the possible trading surplus, the area between the induced supply and demand curves. This surplus is the maximum sum of all buyers' and sellers' earnings in a period. Efficiency is measured as the sum of subjects' actual earnings, expressed as a percentage of the maximum possible.[4] Thus efficiency in a theoretical competitive equilibrium is 100%.

Of course, the standard prediction from any introductory price theory course is that the efficient, competitive outcome will be observed. If there is any discussion of the trading rules that give rise to this prediction, recourse would likely be made to the efforts of the fictional Walrasian auctioneer operating in a market of passive price takers. But in truth, price decisions are negotiated by strategic traders who operate under institutional rules that determine the timing and source of price offers and counteroffers. As intimated above, these rules can importantly affect market performance. Before beginning, the experimenter must decide on an appropriate trading institution.

Although most consumer purchases are made without negotiation at prices posted by sellers, there is a rich variety of alternative trading institutions in which prices are negotiable. Prices on the New York Stock Exchange, for example, are negotiated through a specialist on the "floor." This centralized trading process is implemented in the laboratory by allowing bids and asks to be submitted and displayed publicly, subject to an improvement rule: a seller must improve (lower) the current ask, and a buyer must raise the current bid. Thus ask prices fall and bid prices rise in a "double auction," and trade occurs when someone accepts another's proposal. Consider the contract sequence on the right side of figure 2, where the supply and demand structure is reproduced on the left. The eight dots in the vertical slot for period 1 represent the transaction prices for the eight units that were sold; these dots are listed in the order in which trades occurred. Only 7 units were traded in periods 2 and 3, and by period 3 all transactions

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[4] See Plott (1989) and Davis and Holt (1993e) for a discussion of the limitations of this and other measures of performance used in laboratory experiments.

prices were in the competitive price range.

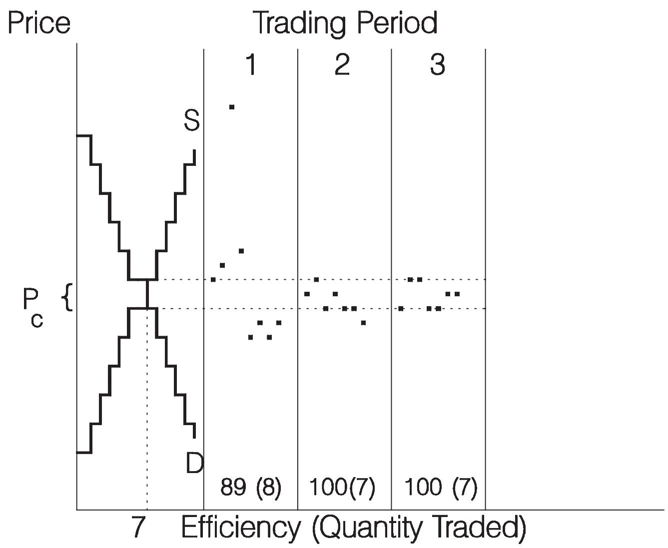

Figure 2. Price Sequence for a Double Auction
(Key: ■ contracts.)

The convergence results in figure 2 are quite typical. Although double-auction experiments do not even come close to satisfying the perfect-information and large-numbers assumptions that go with textbook treatments of perfect competition, laboratory trading reliably converges to efficient, competitive outcomes (Smith, 1982a). Indeed, the contrast between the clarity of the data and the implausibility of the Walrasian assumptions could not be more dramatic, which makes this institution a very effective teaching device. This convergence to the competitive price has been observed for such a wide variety of supply and demand configurations that structural variables seem to be almost irrelevant.[5]

Since the strong convergence characteristics of double auctions are typically cited most prominently in surveys of laboratory market research, the general perception is that market experiments provide reassurance for those who believe in Adam Smith's "invisible hand," and surprises for those who do not. This perception is reinforced by the tendency of textbooks to focus on competitive, Walrasian results of market experiments. Kreps (1991, p. 198), for

[5] Some small effects of market power on double auction prices are reported in Holt, Langan, and Villamil (1986) and in Davis and Williams (1991). The presence of significant fixed costs can also degrade performance in double auctions (Van Boening and Wilcox, 1992).

example, notes that

> "These experiments do not quite get to the level of generality of a Walrasian equilibrium for a general equilibrium with many interdependent markets. But the repertory of experiments is growing quickly and, except for a few special cases, those experiments that have been run are consistent with the notion of Walrasian equilibrium. All in all, they make Walrasian equilibrium look quite good."

Although Kreps seems to be referring to the double auction results, the general equilibrium implications are unjustified if many or most markets in an economy are not organized as double auctions.[6]

In fact, many markets are characterized by prices that are advertised or posted for significant time intervals. This price-posting process is implemented in the laboratory by letting each seller choose a price and a maximum quantity to offer at that price. After all sellers have confirmed their choices for the period, the prices are communicated to all buyers and sellers. Then buyers are selected one at a time, in a random order, to shop from one of the sellers who is not out of stock. Thus all sales are made at the posted prices, which cannot change until the beginning of the next period. Some experiments are conducted with human buyers, and others use simulated (demand-revealing) buyers that are programmed to purchase all profitable units. If buyers reveal demand, this posted-offer institution corresponds to a theoretical Bertrand price-setting model with capacity constraints and with a "rationing rule" determined by random buyer selection.

The asymmetry and rigidity of the price negotiations have the effect of providing a bargaining advantage to sellers. Figure 3 shows the price sequence for a posted-offer market that was conducted with the same supply and demand conditions discussed above.[7] Only 4 units sold in the first period, as indicated by the small boxes (■); the prices of unsold units are indicated by plus signs (+). This market shows a common tendency for posted prices to hang above competitive levels, which raises sellers' earnings relative to those of buyers. Overall efficiency measures, shown in figure 3 below the contract dots for each period, are about ten to twenty

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[6] There have been some experiments in which double auctions are used in several related markets, and general equilibrium predictions are surprisingly accurate, e.g., Williams, Smith, and Ledyard (1986), Goodfellow and Plott (1990), and (discussed below) Lian and Plott (1993).

[7] The calculation of Nash equilibrium prices for designs like that in figure 3 is discussed in section IV below.

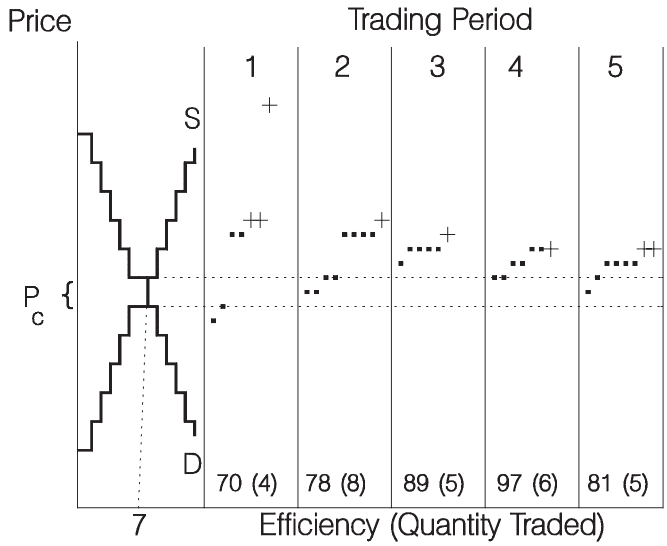

Figure 3. Price Sequence for a Posted-Offer Auction
(Key: + posted prices, ■ units sold.)

percent lower than for comparable periods in the double auction in figure 2. This session is typical; compared to double auctions, laboratory posted-offer markets converge to competitive predictions more slowly (Ketcham, Smith and Williams, 1984) and less completely (Plott, 1986, 1989). Even in non-monopolized designs with stationary supply and demand functions, traders in a posted-offer market generally forego about 10% of the possible gains from trade, whereas traders in a double auction routinely obtain 95-98% of the total surplus in such designs (Davis and Holt, 1993e, chapters 3 and 4).

Other differences between double auctions and posted-offer auctions have been carefully documented. In double auctions, competitive outcomes are consistently observed with very thin markets and even with price-fixing conspiracies (Isaac and Plott, 1981; Clauser and Plott, 1991). The effects of monopoly and significant market power are also surprisingly small (Smith and Williams, 1988, Holt, Langan and Villamil, 1986, and Davis and Williams, 1991). The research reviewed below indicates that none of these conclusions apply to posted-offer trading.

These well-known differences lead naturally to a consideration of the effects of adverse conditions that are quite common in naturally occurring markets. In particular, if posted-offer markets converge to competitive outcomes slowly, what will happen when the competitive price is shifting in response to demand or supply shocks? And what would be the effect of price-fixing conspiracies or of capacity constraints that produce concentration measures that are not unusual for producer goods markets?

A number of important policy issues arise from the parallels between the laboratory posted-offer institution and many retail markets. Factors that affect the success of conspiracies, for example, are of obvious interest to antitrust economists. In macro contexts, a sluggish response of posted prices to unanticipated demand and supply shocks could produce disruptions with interesting Keynesian implications.

Drawing general conclusions from laboratory posted-offer experiments must be done with caution, as there are many differences between laboratory and natural markets. These differences do not arise because laboratory data are a consequence of *an* experiment, but because they are the result of the *wrong* experiment. Successful conspiracies in laboratory posted-offer markets, for example, may say little about behavior in naturally occurring markets in which sellers can offer discounts from their posted prices. Similarly, many natural markets differ from the standard posted-offer implementation in that shopping is not costless. Consumer search costs potentially give sellers some market power over buyers, and may generate higher prices, holding constant other structural conditions.

Perhaps the greatest difference between the laboratory and the economy is complexity. The relative simplicity of a laboratory economy can limit the usefulness of experimental methods. In some respects, however, this limitation is no more condemning that the fact that theory is also a simplification. We can compare the predictive power of alternative theories under ideal "best shot" laboratory conditions and under conditions that stress the theoretical assumptions in limited and carefully chosen dimensions. In such cases, simplicity is a desirable property of an experiment. Relatively more complexity is essential in other cases. For example, the poor response of posted-offer markets to demand shocks suggests Keynesian price rigidities, but an experimental analysis of such rigidities would require a multi-market setup.

These modifications of the posted-offer institution can be accomplished in controlled experiments. Indeed, analysis of discounting and search costs is ideally suited to experimentation, since it is nearly impossible to find two markets outside the laboratory that are identical except for these institutional details. Although there have been few if any multi-market experiments with posted prices, there are an increasing number of multi-market double auction studies (see note 6 above).

The rest of this paper is organized as follows. The next three sections survey recent research on price and performance in the posted-offer institution under adverse conditions. The effects of unanticipated demand shocks are reviewed in section III. Section IV pertains to tacit cooperation among sellers, which is facilitated by the existence of market power, and section V pertains to explicit collusion (price-fixing). Sections VI and VII summarize our own experiments in which the standard posted-offer institution is modified to incorporate discounts and search costs. The final section contains a conclusion.

III. Demand Shocks

Since prices in posted-offer markets tend to converge slowly and from above when the demand and supply structure is stationary, it is natural to consider the adjustment path when structural conditions are shifting from period to period. In the setup in figure 4, for

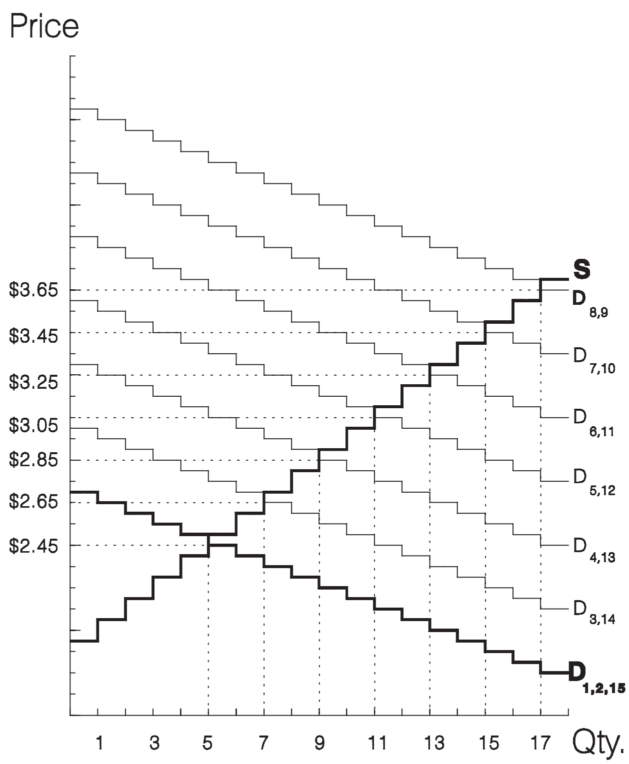

Figure 4. Supply and Demand Arrays for a Trend-Demand Design

example, the bolded demand and supply curves used in the first two periods result in a theoretical price of $2.45. Demand shifts in subsequent periods raise the equilibrium price by 20 cent increments, until a price of $3.65 is reached in periods 8 and 9. This is followed by inward demand shifts in the final 6 periods. This generates the "hill-shaped" equilibrium price paths shown by the stepped solid lines in figure 5. In experiments conducted with similar designs, all value and cost information is private, so that sellers get no direct information about the demand shifts.

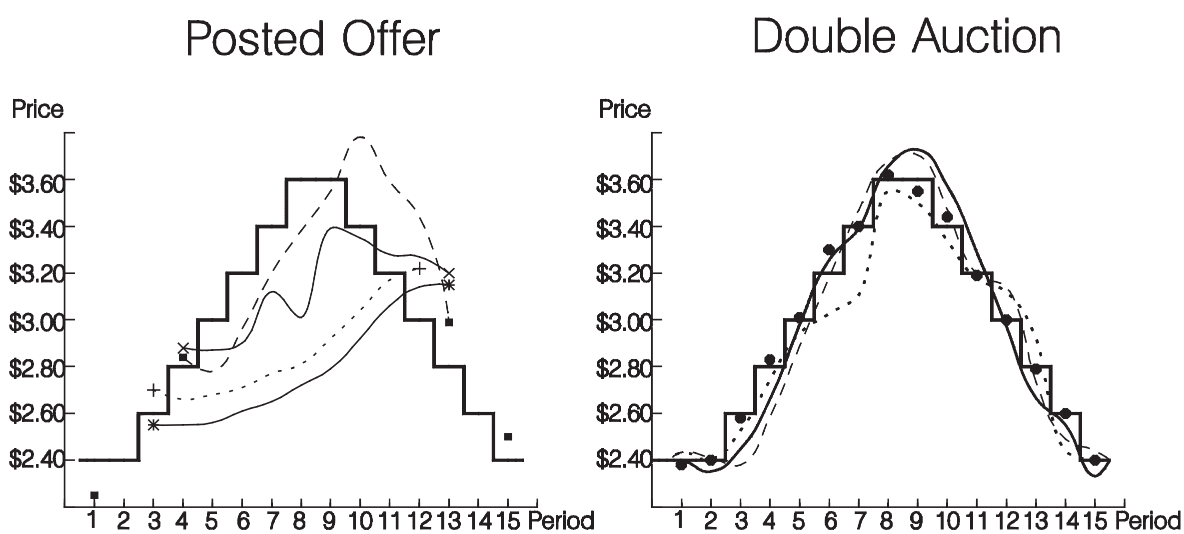

Figure 5. Mean Contract Price Paths in a Trend-Demand Design
(Key: bolded steps = competitive equilibrium price path; curvi-linear lines = mean contract prices for individual sessions; bolded dots in the right panel = mean of closing prices.)

Davis, Harrison, and Williams (1993) report data for posted-offer and double auction markets in this trend demand design. The difference in performance across institutions is evident from comparison of the curvi-linear average price paths for the four posted-offer markets, shown in the left panel of figure 5, with price paths for the three double-auction markets in the right panel. Although price response in the double-auction sessions is not flawless, mean prices generally move with the underlying equilibrium predictions. In contrast, the posted-offer prices tend to start low and drift slowly upward until they cross the underlying equilibrium, at which time sales quantity falls, or drys up altogether as indicated by the breaks in the contract-price curves. These posted-offer markets only extract about half of the possible trading surplus (48% on average), as compared with the nearly full extraction in the comparable double-auction markets (98% on average).[8]

The posted-offer auction differs from the double auction in two main ways: the price posting process is one-sided, and there is less price flexibility. Davis and Holt (1993d) report a series of treatments that incorporate aspects of price flexibility that can be found in many markets. The large efficiency losses from posted pricing in the trend demand design are not eliminated by introducing by allowing buyer-specific discounts (discussed below in section VI) or "clearance sales" at prices below the posted levels. In particular, the clearance sale treatment gave sellers a chance to move unsold inventories with a second price posting in each period.[9] These modifications produced modest improvements in price-tracking, and efficiency increased from about 50% to about 66% in each treatment. Nevertheless, market prices still largely failed to track underlying equilibrium price alterations.

A possible problem with computerized posted-offer auctions is that sellers have difficulty gauging the depth of excess demand at the posted prices. It is not unreasonable, however, for a seller who stocks out at an advertised price to be able to observe some or all of the frustrated buyers. We are currently conducting an experiment in which the posted-offer procedure is modified to provide sellers with an exact count of unfilled orders, using the shifting demand structure of figure 4. Like the discounting modifications discussed above, this excess-demand information only resulted in modest improvements in price tracking and efficiency; trading dried up completely in the last several periods of all three sessions run to date.

To summarize, unanticipated demand shocks produce a sluggish price response in posted-offer markets, and in particular, negative demand shocks can cause market trading to collapse as prices do not fall rapidly enough. This collapse is suggestive of the type of microeconomic inflexibilities that cause macroeconomic disruptions. There are few experiments motivated by

8 The poor response of posted-offer markets to a single, unanticipated demand shift was first noticed by Hong and Plott (1982).

9 The clearance sale treatment was approximately the same at that used in the stationary demand-and-supply markets reported by Mestelman and Welland (1993).

macroeconomic phenomena, and these do not produce severe business cycle fluctuations.[10] For example, Lian and Plott (1993) set up an ambitious experiment with labor and goods markets that were subjected to monetary shocks. They report that prices in their markets moved toward Walrasian competitive levels, without severe disruptions. Since all markets were double auctions, this raises the question of whether behavior changes when prices are posted. The poor response of posted-price markets to demand shocks could provide a simple justification for the price rigidities that are central to Keynesian predictions. We are currently investigating this issue.

IV. Tacit Collusion and the Exercise of Market Power

A monopolist has the market power to raise price profitably above the competitive level, and single sellers are able to exercise this power much more effectively in laboratory posted-offer markets than in comparable double-auction markets (Smith, 1981). This section surveys work on the effects of market power in non-monopolized markets with posted prices.

Market power can be defined to be the unilateral incentive of one or more sellers to raise price above a common competitive level.[11] Holt (1989) suggested that the presence or absence of market power may explain why posted-offer prices sometimes lock onto competitive predictions and sometimes hang above those predictions. Intuitively, it can be profitable for a seller to raise price when other sellers' capacities are sufficiently limited; in this case, the effect of the price increase can more than offset the loss of sales quantity, especially if the lost sales are for relatively high-cost units. Note that the existence of market power depends critically on the capacities and costs of the various sellers; a seller with a large number of marginally profitable, high-cost units is more likely to be willing to withhold quantity than a competitor who has a very limited capacity. A reallocation of units from one seller to another can create or destroy market power. Thus, we were not surprised that Mestelman and Welland report that a reallocation of units, holding the aggregate supply function constant, can alter the average prices

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[10] Rustichini and Villamil (1992), however, construct a theoretical model in which "sticky" equilibrium prices arise as a result of correlated demand shocks.

[11] Holt (1989) also discusses a related notion of "equilibrium market power," which exists when the noncooperative equilibrium for the single-stage market pricing game results in prices that exceed competitive levels.

in posted-offer auctions.[12, 13]

This observation that capacity reallocations can affect prices led us to consider a design in which a reallocation changed the Nash equilibrium price from the competitive price (Bertrand result) to higher (randomized) prices over the range spanned by the "Edgeworth cycle." Consider Design 1 on the left side of figure 6. As indicated by the seller numbers below each unit, sellers S1-S3 each have 3 units, and S4 and S5 each have a single unit. The demand curve has a vertical intercept of *r* and intersects supply at a range of prices from the highest competitive price, p_c, to the level of the highest cost step, *c*. No seller has market power in this design, since

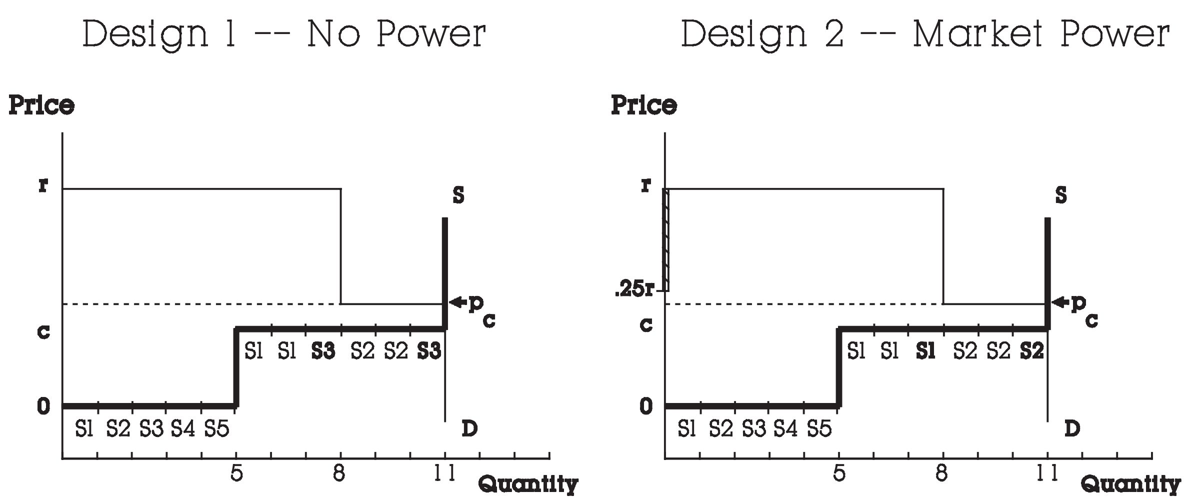

Figure 6. Supply and Demand Arrays for a No-Power/Power Design

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[12] The experiment is described in Mestelman and Welland (1993). The effect of the reallocation of units was reported at a presentation of the Economic Science Association meetings in October 1992.

[13] Moreover, market power can be insidious. For example, when organized under posted-offer rules, seller S1 in the figure 1 design has market power in the following sense: In a single-period game, buyers have no incentive to withhold profitable purchases after prices are posted. If all sellers choose a common price of 1.40, seller S1 is earning nothing if the second unit sells. A careful count of buyers' units shows that a unilateral price increase of 10 cents will still allow seller S1's first unit to sell, unless buyer B1 is chosen to shop last, an event that occurs with probability 1/6. Thus this seller's expected profit goes up if price is increased above the highest competitive price. Although it is often straightforward to demonstrate the existence of market power, the asymmetry of agents in many designs prohibits identification of a Nash equilibrium. This led us to construct the designs in figure 6, discussed below.

a unilateral price increase above a common price p_c will result in no sales. Market power is created by giving seller S3's two high-cost units to S1 and S2, as shown in Design 2 on the right side of figure 6. Now each of the large sellers, S1 and S2, has 4 units. If one of these sellers were to raise price unilaterally to the demand intercept, *r*, one of these 4 units would sell since the other 4 sellers only have enough capacity to sell 7 of the 8 units that are demanded at prices above the competitive level. By making the demand intercept high relative to the high-cost step, we make such deviations profitable for the two large sellers, thereby creating market power. In this case, it is possible to calculate the price distributions in the mixed-strategy equilibrium, by equating sellers' expected payoffs to a constant (since a seller would only be willing to randomize if expected payoffs are independent of price on some range).[14] For Design 2, the range of randomization is shown as the darkened region on the vertical axis (see Davis and Holt, 1993b, for details). By holding the number of sellers and the aggregate supply and demand arrays constant across the two designs, we are able to attribute price differences to the creation of market power and not to other factors such as a small number of sellers or a low excess supply at supra-competitive prices.

Figure 7 shows the results of a session in which 30 periods with the Power design were followed by 30 periods of the No-Power design. The period numbers and treatments are shown at the bottom of the figure. The supply and demand functions are reproduced on the left side (on a different scale from figure 6) to indicate the relative positions of the key price prediction: the competitive price is 309. Demand was determined by a passive, price-taking simulated buyer, and sellers were told the number of periods and all aspects of the demand and supply structure. In each period, *S1*'s posted price is plotted as a box, *S2*'s price is plotted as a cross, and the other three small sellers' prices are plotted as dots. In all but one of the first nine periods of this session, seller S2 (cross) stays at the demand intercept price, 589, selling the residual demand

[14] The calculation of mixed-strategy equilibria is further complicated by the step-function nature of supply and demand in market experiments. Holt and Solis-Soberon (1992) show how the equilibrium price distributions can be calculated in the presence of the discontinuities that result for the trade of discrete units in the laboratory. Holt (1994) shows that the mixed strategy equilibrium is the limit of the Bayesian/Nash equilibria in pure strategies for games with incomplete information as the random payoff differences collapse to a point in the limit. This paper extends the "purification" argument to market games with payoff discontinuities that result from the profit advantage of having the lowest price.

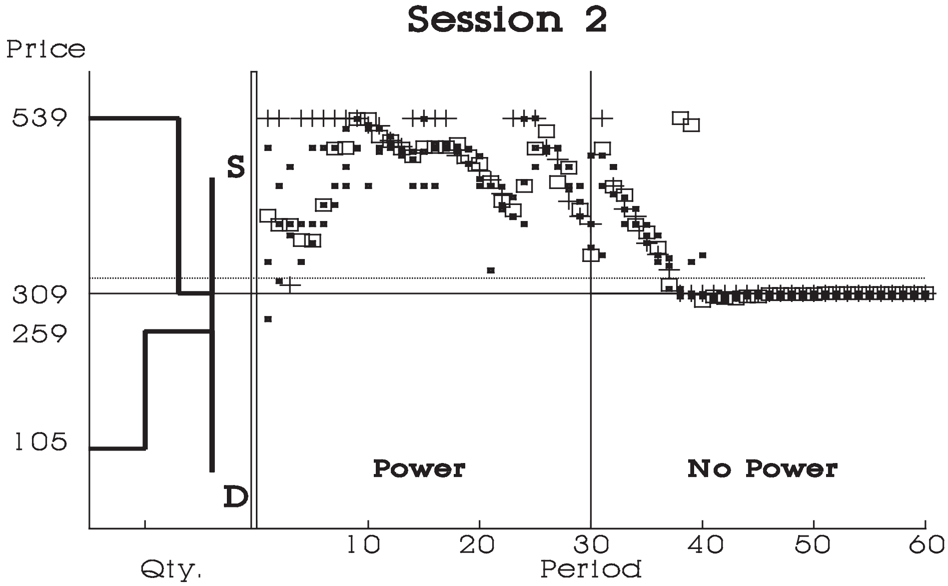

Figure 7. Price Series for a Power/No-Power Sequence
(Key: S1's prices are indicated by boxes, S2's prices by crosses, and the other prices by dots.)

of 1 unit. This action lured the other sellers up, and seller S1 (box) reached the demand intercept price in period 9. Then S1's (cross) price cut in period 10 started a general price decline, which was stopped as cross goes back up to 539 for four periods. The final 12 periods of this treatment contain two relatively tight price cycles. Overall, prices stay above competitive levels, which produces inefficiencies.[15]

Units are reallocated after period 30 to take away market power. The high price by S2 (cross) results in no sales, and the aggressive competition that follows drives prices to the competitive (and now Nash) levels. This market efficiently exploits all gains from trade in the absence of market power.[16] Market power also resulted in large price increases in five other sessions, holding constant the number of sellers and the aggregate supply and demand structure.

[15] When all sellers randomize in the Edgeworth-cycle range, market efficiency is reduced because consumers are unable to obtain units with values on the lower demand step, even though the consumers' values for these units exceed the sellers' costs of producing the three units at the margin.

[16] Notice that convergence to the competitive equilibrium was not immediate in the second half of the session shown in figure 7, so being able to do a total of 60 periods (30 per treatment) with a computer network produced a much more convincing outcome than would have been the case with half as many periods. Many variations, such as letting buyers request secret discounts, are even more time consuming, and computerization is even more useful in such environments.

In fact, the price-increasing effect of market power was considerably greater than the difference between the Nash/Bertrand price in the No-Power treatment and the mean of the mixed price distribution in the Power treatment. Since explicit communications between sellers were not permitted, we use the term "tacit collusion" to describe this ability of sellers to raise prices above the levels determined by a noncooperative equilibrium. To summarize, market power has a double impact: it raises the noncooperative mean price prediction, and it facilitates tacit collusion that raises prices above the noncooperative levels.

V. EXPLICIT COLLUSION

Ever since Adam Smith, economists have believed that sellers often conspire to raise price, and that such conspiracies fall apart if some sellers defect.[17] Price-fixing is difficult to study since it is usually illegal and the participants do their best to hide the evidence. Without good data on participants and their costs, it is difficult to evaluate the nature and success of collusion, and the causes of breakdowns in pricing discipline. Such data problems do not exist in the laboratory, and controlled opportunities for conspiracy can be allowed, holding constant other structural and institutional elements that may facilitate price fixing.

Isaac and Plott (1981) allowed sellers in double auctions to discuss prices between trading periods. These conspiracies, however, were not very effective in actually raising transactions prices in the fast-paced competition of a double auction. Isaac, Ramey, and Williams (1984) later showed that price-fixing conspiracies can be much more effective in posted-offer auctions, since sellers do not have the temptation to shade prices once they are posted.

The effects of seller collusion in posted-offer markets reported by Davis and Holt (1993c) can be seen by comparing the price sequences without collusion (figure 8a) and with collusion (figure 8b). The underlying supply-and-demand structure for each session is shown on the left, where the three buyers' reservation values and the three sellers' marginal costs are measured as deviations from the highest competitive price in the range of overlapping demand and supply.

[17] In fact, Smith's oft-quoted warning about the likelihood of price fixing is followed by an important qualification: "In a free trade an effectual combination cannot be established but by the unanimous consent of every single trader, and it cannot last longer than every single trader continues of the same mind. The majority of a corporation can enact a bye-law with proper penalties, which will limit the competition more effectually and more durably than any voluntary combination whatever." (Smith, 1776, p. 144).

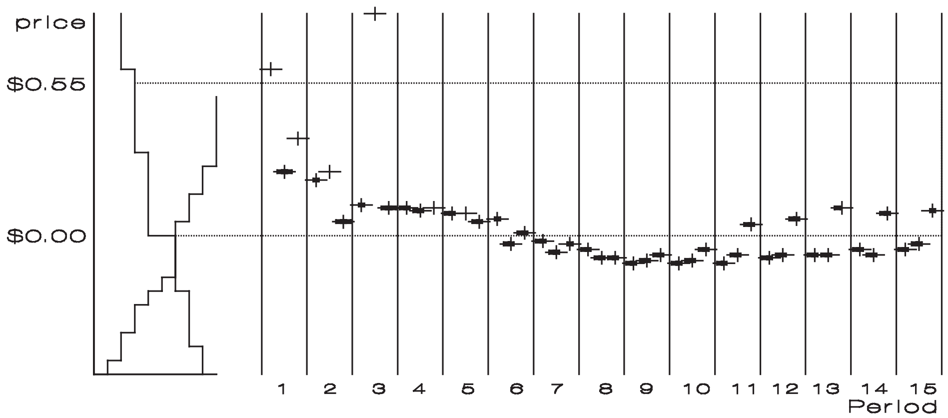

Figure 8a. A Session with No Seller Conspiracy and No Discounts
(Key: + posted prices, ■ units sold.)

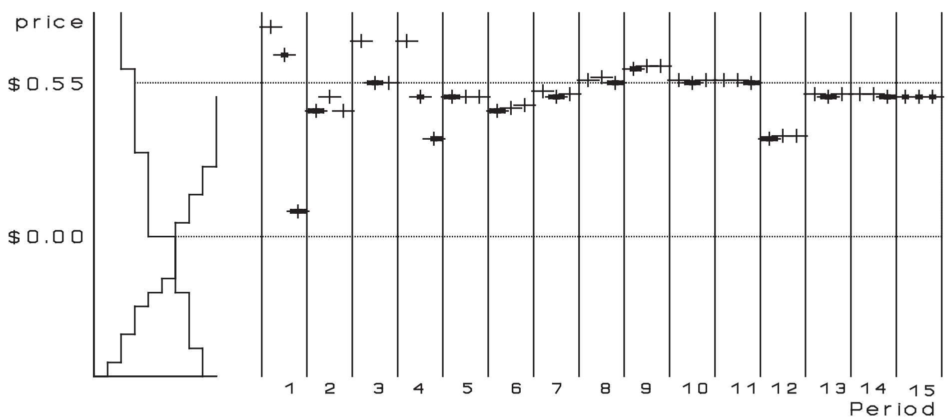

Figure 8b. A Session With Seller Conspiracy and No Discounts
(Key: + list prices, ■ units sold.)

There was no collusion for the session shown in figure 8a, and both posted prices (indicated by + marks) and transactions prices (indicated by the small boxes) quickly fall to the competitive range, which is bounded by the lower dotted line.

Procedures for the collusion session shown in figure 8b were identical, but sellers were allowed to discuss prices, quantities, etc. at the beginning of each period while buyers were taken from the room (under the pretext of assigning buyer demand incentives).[18] Sellers could not discuss private information about their costs or previous transactions, and after colluding, they

[18] Buyers were taken out of the room in exactly the same way in both sessions, but seller collusion was only permitted in the session shown in figure 8b.

returned to their visually isolated booths before entering prices independently via their keyboards. Despite the competitive nature of the market structure and Bertrand pricing rules, sellers were able to fix and maintain prices near the joint-maximizing level, which is $0.55 above the competitive level and is indicated by the upper dotted line.[19] The price crosses for sellers S1, S2 and S3 are listed in order in the vertical stripe for each period, which reveals a "phases of the moon" bid rotation, with S1 bidding low in period 6, S2 in period 7, etc. Aggregate consumers' and producers' surplus was about 30% lower for the session in figure 8b than for the very efficient outcome in figure 8a. These are results for are typical for posted-offer conspiracies and are well known (e.g., Isaac, Ramey and Williams, 1984).

VI. DISCOUNTS

Markets for major purchases typically differ from the typical posted-offer institution in that sellers can offer private discounts from the "list" prices. The effectiveness of conspiracies in such markets is important for antitrust policy, since many of the celebrated price-fixing cases, like the electrical equipment bidding conspiracy of the late 1950's, involve producer goods. Moreover, sales contracts and practices that may deter discounts have been the target of antitrust litigation, as in the Federal Trade Commission's *Ethyl* case.[20]

Davis and Holt (1993c) conclude that opportunities to offer secret discounts to specific buyers can break down price-fixing conspiracies among sellers. The session shown in figure 9 used the same procedures as in the conspiracy session in figure 8b, except that buyers could subsequently request discounts from particular sellers (by pressing a discount-request key). A seller could respond by typing in the original list price (no discount) or by typing in a lower discount price, which was not observed by any other buyer or seller. After some initial adjustments, sellers agreed on a common list price in period 3 and in all but one subsequent period. In periods 7 and 8, seller 2 began secret discounting, as indicated by the dots below the middle "+" sign. These discounts caused S1 to have no sales in these periods, and S1 responded with a deep discount in period 9 and a lower list price in period 10. After this point, discounts

[19] The joint maximizing price is a nickel below the demand step at $0.60, because buyers were required to pay a nickel shopping cost each time that they approached a seller.

[20] This case is summarized by Grether and Plott (1984), who report laboratory experiments in which the practices raise prices above benchmark competitive levels. A theoretical explanation of the Grether and Plott results is provided by Holt and Scheffman (1987).

were pervasive, and the outcome was relatively competitive. This competitive outcome is similar to the results of two other sessions with discounting.[21]

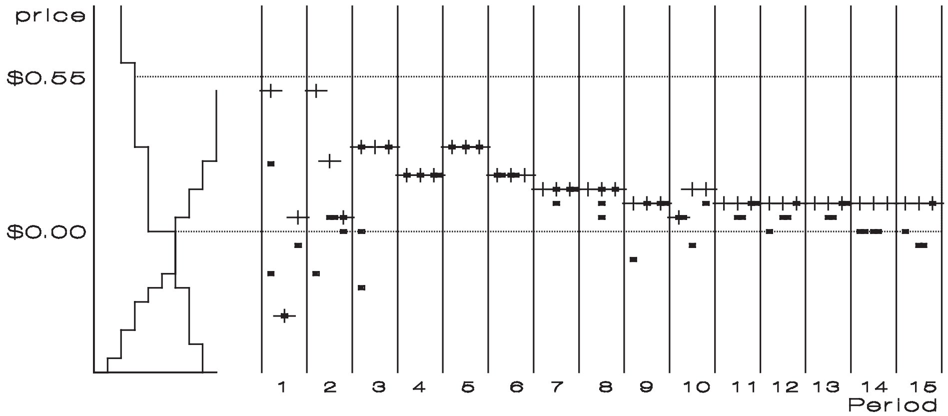

Figure 9. A Session with Seller Conspiracy and Secret Discounts
(Key: + posted prices, ▪ unit transactions prices.)

If secret discounts hamper conspiracies by reducing verifiable price information, institutional features that increase the monitorability of price agreements may have the opposite effect. In particular, the *ex post* reporting of sales information to a trade association may facilitate collusion, even when substantial discounting opportunities are available.[22] Clearly, the publication of sales information may not directly reveal discounting, since price concessions can often be hidden in reduced delivery and service fees, and sellers who defect from an illegal agreement will not report their defections. Nevertheless, the public revelation of large sales changes may signal aggressive discounting, and may therefore temper discounting behavior (Stigler, 1964).

Initial results in Davis and Holt (1993c) confirm the anti-competitive effect of the *ex post* provision of sales information. In two of three sessions conducted, near-monopoly transactions prices were generated when conspirators could offer discounts, but where individual sales quantities were publicly revealed to all sellers at the end of each session. Although effective, this provision of fully accurate sales information is, perhaps, unrealistically precise.

One area for further research is to determine whether one can infer bid rigging only from

[21] Davis and Holt (1994) report that discounting opportunities do not necessarily result in lower prices when sellers are not able to communicate.

[22] The link between trade associations and conspiracy has been a matter of continuing concern to antitrust authorities. For example, in their review of Department of Justice horizontal price-fixing cases between 1963 and 1972, Hay and Kelley (1974) found that trade associations were present in almost all cases with fifteen or more conspirators.

the pattern of submitted bids. For example, losing bids may be less correlated with costs in a conspiracy than would be the case with independent bidding, as suggested by an analysis of highway construction bidding in Porter and Zona (1993). We plan to investigate this issue in the context of a design in which individual sellers' costs vary independently and randomly from period to period.

VII. SEARCH COSTS

The absence of buyers' shopping costs in standard posted-offer experiments is notable in view of the dramatic effects that such costs can have in theoretical models. Diamond (1971), for example, concludes that, in the absence of publicly posted price information, the existence of even a small search cost could lead to monopoly pricing. The intuition is straightforward: No buyer with one price quote would want to search for a second, unless the new quote is expected to be lower by at least the amount of the search cost. Then each seller has an incentive to price slightly *above* any common price, and the noncooperative equilibrium in a single-stage game is that price be raised to a monopoly level. This result is viewed as a paradox, since a "small" search cost produces high prices, but a zero search cost would produce the usual Bertrand incentives that drive prices to competitive levels, in the absence of capacity constraints and other imperfections. Given the difficulty of controlling and measuring information flows in natural markets, the laboratory is an ideal place to evaluate the Diamond paradox and its proposed resolutions.

Davis and Holt (1993f) report an experiment designed to determine whether prices in an otherwise competitive environment will rise to monopoly levels with the introduction of search costs that are *not* infinitesimally small. The supply and demand arrays for these sessions are shown on the left side of figure 10. The identity of the buyer associated with each value step is printed above the demand curve. The three buyers are symmetric, each with units valued 70 and 30 cents above the competitive prediction. In a parallel fashion, costs for the three sellers are printed below the supply curve. Each seller has one low-cost unit and 3 units at the competitive price P_c, normalized to zero for this discussion. The relatively large excess supply at any price above P_c makes the market very competitive, and there is no market power in the sense that it is a (weak) Nash equilibrium for each seller to offer 2 units at the competitive price.[23]

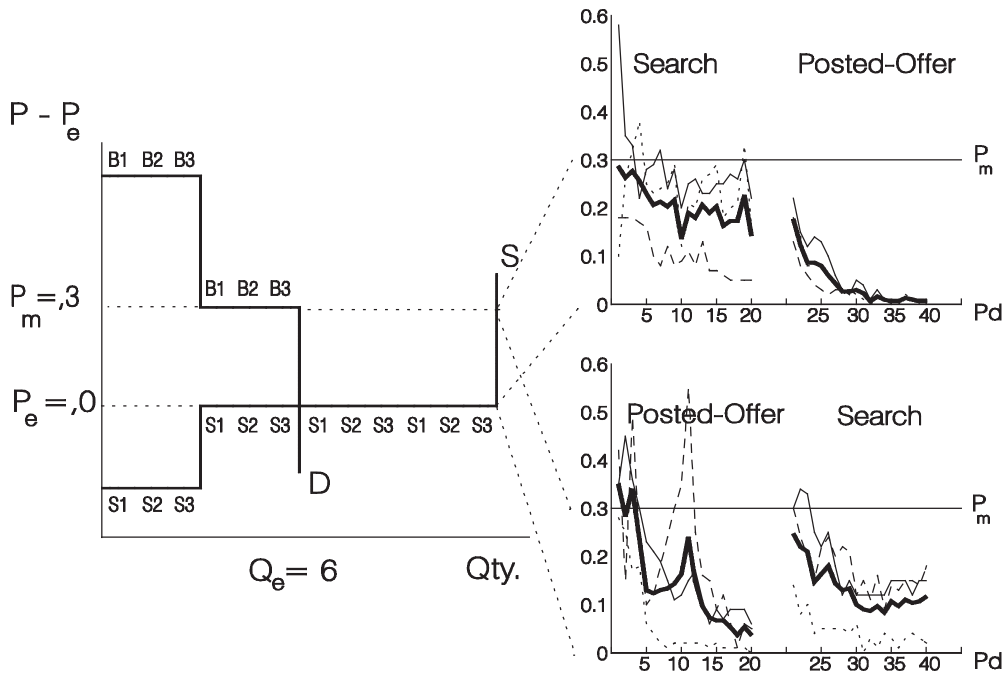

Figure 10. Mean Price Data for Six Sessions, with and without Search Costs
(Key: + posted prices, ■ unit transactions prices.)

Six 40-period sessions were conducted under standard-posted offer trading rules, except that 1) buyers had to pay a 15 cent search cost each time that they approached a seller, and 2) prices were not publicly displayed in half of the periods. In these no-information "search" periods, the buyer had to pay the search cost in order to see a seller's price. A buyer could either buy at the posted price (by pressing "p" on the keyboard) or shop elsewhere (by pressing "s"). To control for possible order-of-sequence effects, the order of the search and posted-offer treatments were alternated across sessions.

The period-by-period paths of mean contract prices are shown on the right side of figure 10, where separate sessions are distinguished by the thin dotted, dashed and solid lines. The

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23 The market design differs from standard search models in that sellers' marginal costs and buyers' reservation values are not constant. The high-value and low-costs steps were added to give both competitive and monopoly predictions a realistic chance, since it is rare to observe stable outcomes in which one side of the market earns nothing. We anchored our design on a minimum earnings of 25 cents per trader per period. For this reason, the cost step for the first unit is 25 cents below the competitive price. Symmetrically, a buyer's value step at 40 cents above the monopoly price guarantees each buyer a minimum earnings of 25 cents at the monopoly outcome, after netting out the 15 cent shopping cost (discussed below).

thick line represents average prices, pooled across sessions. Two observations are readily apparent. First, information makes a difference. Regardless of the order of presentation, prices at the end of the search treatment are higher than prices at the end of the corresponding posted-offer treatment. Second, the Diamond result is not observed. Despite the significant order-of-treatment effect, prices do not cluster about the monopoly price P_m, even in the sessions in the upper panel where the search condition came first.

We were somewhat surprised by the failure of relatively large search costs to yield uniform monopoly outcomes. Moreover, the results are puzzling given that Grether, Schwartz and Wilde (1988) observe monopoly prices in 3 out of 4 sessions, in a very different search-cost design.[24] One possible explanation is that they implement the standard assumption that buyers see the entire list of *actual* price postings in each period before making a search decision; all sellers' posted prices are listed on a blackboard, without seller identifications. In one treatment, a buyer can pay a search cost to obtain a sample of the prices of two or more randomly selected sellers, so that a purchase can be made at a lower price. A buyer who does not pay the search cost is provided the seller identity of a single randomly selected seller, and any purchase must be made from that seller. In contrast, we decided to not reveal any prices to buyers unless they paid a search cost in a sequential search setup.[25] We were motivated in part by Stahl's (1989, p. 700) argument against "... the dubious assumption that consumers can 'see' deviations by firms before they actually search."

A second possible motivation for the below-monopoly prices observed in our sessions may be due to the fact that the market was indefinitely repeated (we did not announce the final period in any session). Bagwell and Ramey (1992) model an infinitely repeated price-search game in which buyers can elicit lower equilibrium prices by returning to check the prices of sellers who

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[24] Grether, Schwartz and Wilde also observe qualitative conformity between theoretical predictions and data for two additional informational technologies: a nonsequential search model where a subset of consumers is given a sample from the population of price realizations (Wilde and Schwartz, 1979); and a model in which buyers have either high or low costs of purchasing a complete list of sellers' prices (Salop and Stiglitz, 1977). In these models, it is the proportion of more informed agents (with low sampling costs or with a larger sample) that determines whether the outcomes are competitive, monopolistic, or something in between.

[25] There are a number of other procedural and design differences between our sessions and those reported by Grether, Schwartz and Wilde. In particular, we used different participants in each session, whereas Grether, Schwartz and Wilde used the same participants in all 12 sessions "to the extent possible." They used more sellers (5-8), and sellers were allowed to exit to avoid a fixed cost.

have given low prices in the past.[26] The equilibrium price predictions vary continuously between monopoly and competitive levels, depending on the size of the consumer search cost. The role of reputations as a means of generating lower prices may be evaluated by constructing a control treatment where the identities of the sellers are disguised, and randomly reassigned at the beginning of each trading period. Monopoly, or near monopoly pricing in these baseline "no-reputation" sessions would suggest that reputations play an important role in tempering price increases.

VIII. Conclusion and Directions for Future Work

Many, if not most, markets of interest to industrial organization economists are not organized like the centralized (double) auctions that reliably produce efficient, competitive outcomes in a wide variety of laboratory experiments. When prices are posted on a take-it-or-leave-it basis, market competitiveness and efficiency are much more sensitive to factors such as unanticipated demand shifts, market power, and price-fixing. This section summarizes these and other effects, and outlines some directions for our current research.

Unanticipated decreases in demand can cause posted-offer trading to fall off dramatically as sellers fail to reduce prices quickly. These periods of stagnation are not eliminated by the introduction of discounts, clearance sales, and information about excess demand. We are currently working on experiments that sort out the macroeconomic implications of the rigidities inherent in the posted-offer institution.

The creation of market power in posted-offer markets can cause large, consistent increases in prices, even though other factors such as the numbers of sellers and the aggregate demand-and-supply conditions are held constant across treatments. Market power can arise naturally from capacity constraints in these experiments with (Bertrand) price competition. We are currently investigating whether letting sellers choose capacity in advance of the price competition will produce Cournot outcomes in the laboratory, as implied by the theoretical analysis in Kreps and Scheinkman (1983).

As is the case with market power, the effects of price-fixing conspiracies can be dramatic

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[26] In the simpler context of a repeated seller-selection game, Davis and Holt (1993a) find that buyers quite naturally select strategies similar to a loyalty-boycott rule, and that such strategies are quite successful in eliciting cooperation from sellers.

in laboratory markets with posted prices. Our research also shows that conspiracies break down if sellers have the ability to offer secret, buyer-specific discounts from the posted list price. The pro-competitive effects of discounting, however, are mitigated if a “trade association” provides sellers with *ex post* information about each others’ sales quantities. These experimental results support the current antitrust hostility to contracts and industry practices that limit opportunities for secret price negotiations.

Market power can also be created by informational imperfections. Instead of the usual Bertrand incentives to shade on one anothers’ prices, sellers have an incentive to raise price in markets where buyers must pay a shopping cost to obtain a price quote. Shopping costs do raise transactions prices significantly in laboratory experiments, but not to the monopoly levels predicted by the theoretical “Diamond paradox.” To the extent that moderate shopping costs do not produce monopoly prices, the laboratory results provide indirect support for theoretical resolutions of this paradox. Our current research is directed at distinguishing between some of these resolutions, and in particular, those based on the development of sellers’ price reputations.

Despite the inefficiencies and rigidities that characterize posted pricing, this institution offers some important advantages. It became prevalent in the nineteenth century, when the growth of retail establishments made it more difficult for owners to monitor sales clerks. The posting of prices on a take-it-or-leave-it basis also reduces transactions and negotiation costs. In addition, posted prices are easier to advertise, and buyers may prefer a situation in which they know that they are obtaining the best available price from the seller (especially in producer goods markets). For whatever reason, posted price markets are common, and laboratory experiments can be used to evaluate the effects of adverse conditions and imperfections on the performance of such markets.

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