PRICE RIGIDITIES AND INSTITUTIONAL VARIATIONS IN MARKETS WITH POSTED PRICES

Douglas D. Davis and Charles A. Holt*

(Note: figure 6 is missing and figure 3 is incomplete)

Abstract

Standard laboratory posted-offer markets respond slowly and incompletely to demand shocks. In these one-sided markets, where sellers control the setting of prices, very little information is transmitted via the process of exchange. For this reason, traders have trouble distinguishing randomness in their own experience from changes in market fundamentals. This paper reports the results of twelve laboratory markets conducted to assess whether some common variants to standard posted-offer rules can correct the adjustment deficiencies. Although discounting, multiple postings and excess demand information all improve performance, we find that response remains poor, and efficiencies low.

1. Introduction

Goods and services are exchanged under an impressive variety of practices, conventions and conditions; typical trading institutions range from the passive delivery of energy and water at posted prices on an as-needed basis, to the aggressive negotiations in the trading "pits" of commodities exchanges. A fundamental result of laboratory experimentation is that institutional differences have dramatic effects on market performance. These laboratory results can be useful, both in the design of new electronic trading mechanisms, and in the diagnosis of problems with existing institutions.

Notably, the problems caused by imperfections in trading institutions can be much broader in scope than inefficiencies in a particular auction or exchange. "Neo-Keynesian" macroeconomists, for example, often attribute disequilibrium imbalances to price rigidities

---

* Virginia Commonwealth University and University of Virginia, repsectively. Support for this research was provided by the National Science Foundation (SBR 9319842 and SBR 9320044), and the University of Virginia Bankard Fund. Data are archived at FTP address: fido.econlab.arizona.edu. We wish to thank Charles Plott for useful comments on an earlier draft of this paper. The usual disclaimer applies.

brought about by market imperfections of one sort our another.[1] Our study of behavior in laboratory markets suggests that an important cause of the price rigidities may lie in the *posted-offer* trading rules that predominate exchange in many sectors of our economy. This method of exchange, where sellers post prices on a take-it-or-leave-it basis, is both asymmetric (in the sense that the sellers control the terms of exchange by setting prices) and informationally stark (since the only information generated in the market is the public price postings of the sellers and, for sellers, the individual sales quantity). Posted-offer market rules are quite different from the symmetric and informationally-rich negotiations characterizing most financial exchanges. In such *double-auction* markets, sellers and buyers continuously submit public offers and bids to a central location, and a trade takes place when someone on one side of the market accepts the terms proposed by someone on the other side.

Relative to markets organized under double-auction rules, posted-offer markets converge to competitive equilibrium predictions more slowly (Ketcham, Smith and Williams, 1984), and less completely (Plott, 1986). Posted-offer markets are also relatively more susceptible to exploitation by monopolists (Smith, 1981), explicit collusion (Isaac, Ramey and Williams, 1984) and market power (Davis and Williams, 1991). But more to the present point, posted-offer markets respond more slowly to alterations in underlying market conditions than double auctions. In particular, response to demand-side shocks is, quite simply, abysmal (Davis, Harrison and Williams, 1993).[2]

For example, Davis, Harrison and Williams implement a nonstationary design with a series of repeated inflationary, then deflationary demand shocks, over a 15-period sequence. Aggregate demand shifts were accomplished by changing all unit valuations by a constant, while leaving seller costs unchanged. Thus, although the demand shift was not announced, buyers may have inferred it from the alterations in their individual demand schedules. Sellers, on the other

---

[1] Identifying and distinguishing among the possible sources of disequilibrium adjustments is often viewed as the most pressing research task in macroeconomics. "The challenge is to choose between the myriad of ways in which markets can be imperfect, and to decide on the central questions and puzzles to be explained" (Greenwald and Stiglitz, 1993, p. 25).

[2] As indicated by laboratory studies of forecasting behavior (e.g., Daniels and Plott, 1988), expectations do not automatically adjust in response to alterations in underlying conditions. The poor response of posted-offer markets relative to double-auctions is attributable to the capacity of double-auction (but not posted-offer) traders to act on revised expectations within a trading period.

hand, could detect the demand shift only through the course of trading.

Table 1. Average absolute price deviations and efficiencies for posted-offer and double auctions

Session	Mean Absolute Price Deviation	Efficiency
POX1	41	49
POX2	30	46
POX3	47	50
POX4	33	48
Posted Offer Average	**37**	**48**
DAX1	17	98
DAX2	12	98
DAX3	13	99
Double Auction Average	**14**	**98**

Table 1 lists summary measures of price-tracking performance and efficiency, for the four posted-offer auctions (labelled POX1-4) and the three double auctions (labelled DAX1-3) reported by these authors.[3] As is clear from the table, performance in the posted-offer auctions was far inferior by either measure: A standard measure of price tracking is the mean of absolute deviations from the competitive price. These deviations are considerably more than twice as large in the posted-offer sessions than in the comparable double auctions (37 cents vs. 14 cents, on average). Similarly, while the double auctions were uniformly efficient (98% on average), the posted-offer markets tended to extract only half of the possible gains from exchange (48% on

[3] Data are taken from the NovaNet database (contact Davis for access information). In three of the four posted-offer sessions summarized in table 1, trading was continued under stable, low demand conditions for 10 additional periods after the end of the deflationary cycle. For purposes of comparability, calculations are based on the first 15 periods.

average).[4] But it is the pattern of price adjustments and efficiency losses that suggests macroeconomic implications. In the posted-offer markets, sellers revised prices upward only very slowly in response to inflationary pressures, causing prices to lag below the competitive prediction. Similarly, sellers failed to revise prices downward with sufficient speed in the deflationary periods, causing trade to dry up, and even cease altogether.

To the extent that laboratory posted-offer markets parallel relevant features of natural markets, the results of these sessions suggest that trading rules may be a prominent source of rigidities.[5] Many natural "posted-price" markets, however, are less austere than the typical laboratory posted-offer implementation. For example, rather than being arbitrarily restricted to a single price posting for a perishable commodity, sellers often have the capacity to sell off excess inventories by offering secret, selective discounts from the posted prices. Discounting of this type is typical in producer-goods markets, and in consumer markets for big ticket items. In other contexts, sellers may rid themselves of excess inventories via a public "clearance sale."

There is some evidence that discounting capabilities of this type can affect market outcomes. For example, Mestelman and Welland (1993) construct an interesting variation of the posted-offer market by allowing sellers to post a second price after buyers have finished shopping at the original prices for that period. They report that second posting opportunities vastly reduce differences in the convergence process for double-auction and posted-offer markets.[6,7] Similarly,

---

[4] Efficiency is the average proportion of total trading surplus extracted in each period of the session. Formally, let π_j represent the surplus actually extracted in period *j*, and let π_{ej} denote the maximum possible gains from exchange in period *j*, $j = 1 ... J$. Then $E = \Sigma_j \pi_j / J\pi_{ej}$.

[5] It is well known that price stickiness is a part of the posted-offer pricing process (e.g., Hong and Plott, 1982). Rustichini and Villamil (1992) show that price stickiness can be an optimal response for a posted-offer monopolist, given demand uncertainty.

[6] Using inexperienced traders in otherwise standard posted-offer markets, Mestelman and Welland conclude that a second price posting substantially improves both the rate of price convergence, and efficiency. In more complex environments (e.g., where experienced sellers make production decisions in advance of sales, and carry inventories from one period to the next) they conclude that a second price-posting opportunity virtually eliminates differences across institutions.

[7] This two-posting mechanism is but one of a wide set of possible variations from the standard laboratory posted-offer implementation. More general "n-posting" mechanisms are possible, which allow for multiple price and quantity revisions. These more general mechanisms may lead to even more fluid response patterns.

Davis and Holt (1993a), report that the capacity of sellers to offer secret selective discounts severely impedes the success of explicit price-fixing conspiracies.[8]

Still other institutional details common to natural posted-offer markets may substantially improve sellers' capacities to detect changes in underlying demand conditions. For example, the length of queues forming for goods may be a fairly sensitive barometer of excess demand. Standard laboratory implementations of the posted offer have varied with respect to the amount of sales information provided to sellers.[9] However, to our knowledge, no posted-offer implementation has given sellers any information regarding how many units they might have sold at a given price.

The purpose of this paper is to explore the robustness of the price rigidities in posted-offer markets to institutional variations that allow a second price posting, buyer-specific discounts, and that report excess demand information. Specifically, we report the results of twelve sessions in which a series of increases in demand are followed by a series of decreases. In addition to three baseline posted-offer markets, we report three markets where sellers can offer secret discounts from the posted prices, three markets where sellers can attempt to clear out unsold units via a second price posting, and three markets where buyers tell sellers the maximum number of units they would have purchased from them at their posted prices each period. We find that each of these modifications increases the proportion of trading surplus that is extracted. Sizable efficiency losses remain, however, and prices still fail to track the underlying equilibrium. Our results suggest the imperfections observed in our baseline environment are not a consequence of artificial restrictions on price repostings or excess demand information. At least individually, none of these modifications provide the critical information sufficient to allow individuals to

---

[8] Discounting is clearly an important motivation for price adjustments, even when public and nonselective, as in the double auction. Clauser and Plott (1991) isolate the effects of discounting from other institutional features impeding the success of conspiracies in double auctions.

[9] In a discussion of this paper with Charles Plott and Vernon Smith, it became clear to us all that the "standard" laboratory posted-offer market has been conducted under at least two distinct information conditions. In the computerized NovaNet implementation (used by Smith, Williams, Isaac, Coursey and others), as well as in our posted-offer software, sales information is private, and sellers do not find out when other sellers stock out. In contrast, in posted-offer experiments by Plott and colleagues, Mestelman, Welland, and others, sales information is publicly provided to all sellers. The "excess demand revelation" treatment reported in this paper provides roughly comparable public information, and the absence of a sizable treatment effect (discussed below) makes us skeptical that the information makes a large difference in this context.

distinguish randomness in their own experience from alterations in market fundamentals.

The remainder of this paper is organized as follows: The experiment design and procedures are explained below, in section 2. This discussion is followed by a presentation of results in section 3, and some parting comments in section 4.

2. Design and Procedures

The supply and demand arrays for our trend-demand design are illustrated in figure 1. These arrays were induced in the usual way, by providing agents with cost or value incentives at the outset of each trading period. Sellers, for example, were each given a series of unit costs, and were told that they would be paid the difference between these costs and sales prices. Similarly, buyers were given a series of unit values, with the understanding that they would be paid the difference between their unit values and the purchase price(s). Thus, cost and value incentives represent minimum willingness-to-sell and maximum willingness-to-pay conditions. Aggregating these incentives across the sellers and buyers generates market supply and demand curves, such as the bolded supply and demand arrays labeled **S**, and $\mathbf{D}_{1,2,15}$ in figure 1. For the bolded arrays, used in periods 1, 2 and 15, five units are predicted to trade in a competitive equilibrium, at any price between $2.40 and $2.50. The maximum possible gain from exchange is $2.00, or the area between the aggregate demand and supply curves.

Each session consisted of 3 buyers and 3 sellers who, with one exception, made decisions for a series of 15 trading periods.[10] In each period, cost and value incentives were allocated among the agents so as to make expected earnings and transactions quantities as equitable as possible. The inflationary and then deflationary demand shifts were induced by altering unit values for the buyers. The demand curve labelled $\mathbf{D}_{3,14}$ was induced in trading period 3, for example, by increasing each of the period 2 unit values by 30 cents. Similar 30-cent per unit increases were induced in periods 4 to 7. Following a repetition of seventh-period unit values in period 8, all unit values were diminished by 30 cents in each period 9 to 15. In this way, the midpoint of the competitive equilibrium price prediction varies in 20-cent increments from $2.45

[10] We were forced to truncate one of the sessions (LD2) after 13 periods, due to extremely slow negotiations by the participants.

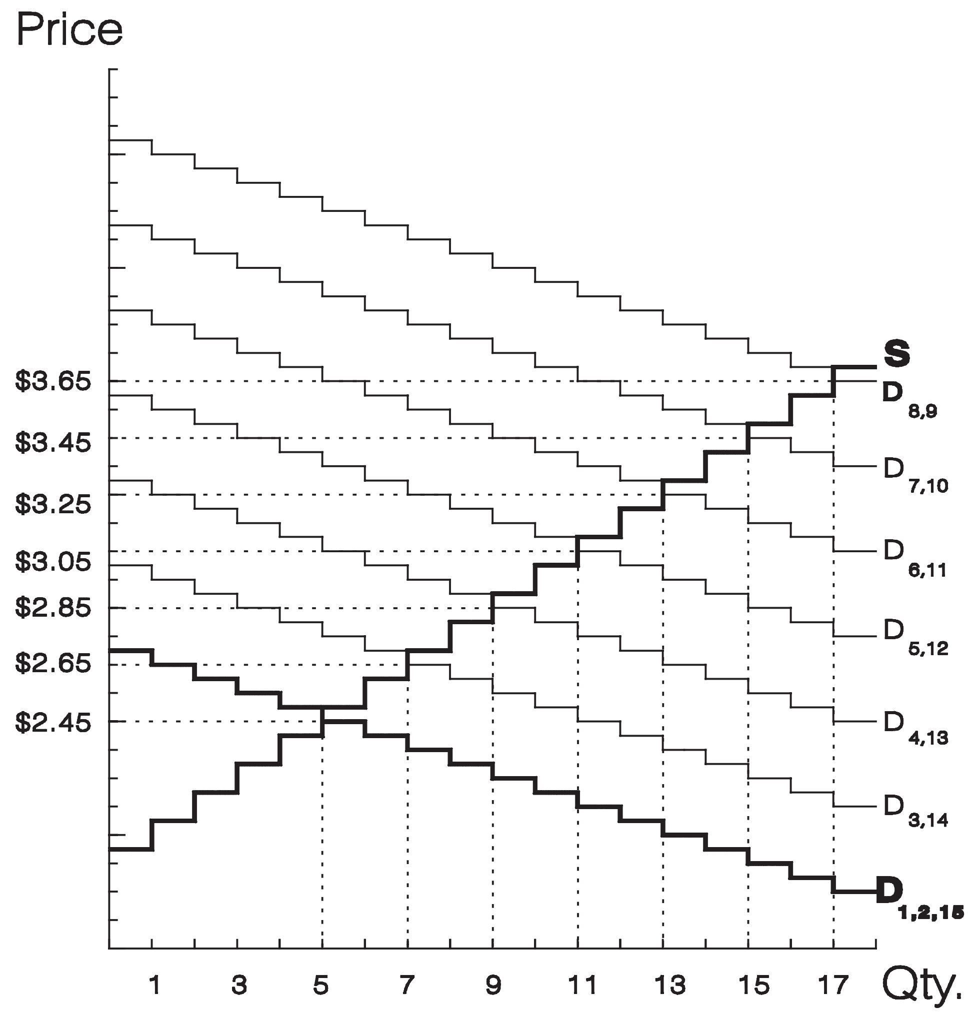

Figure 1. The trend-demand design.

to $3.65, the competitive quantity prediction varies from 5 to 17 units, and possible exchange surplus ranges between $2.00 and $20.40.[11]

All sessions were conducted as variants of the standard posted-offer market, which proceeds as the following two-step sequence: First, sellers simultaneously post prices, which are publicly displayed to all traders. (Sellers also specify maximum sales quantities, which are not publicly displayed.) Then buyers are randomly drawn from a waiting mode, and are given the

[11] Due to an initialization error, this pattern was altered slightly in one of our treatments. In the excess demand revelation sessions (ED1, ED2 and ED3 in table 2), the inflationary sequence was started after period 1. Thus, in these sessions, the low-demand periods are 1, 14 and 15, rather than 1, 2, and 15, as in the other 9 sessions. Although unfortunate, this minor procedural difference did not importantly affect performance.

opportunity to purchase from the sellers, at the posted prices. The trading period ends when all sellers are out of stock, or when all buyers have had an opportunity to shop. For purposes of calibration, a series of 3 sessions was conducted under these posted-offer trading rules.[12]

In the list-discount treatment, sellers simultaneously post prices, and then buyers are randomly selected to shop, as before. While shopping, buyers may request a discount from the posted price by pressing "r" on their keyboard. The buyer's discount-request message then appears on the screen of the appropriate seller, in a way that identifies that buyer as the sender of the request. Negotiations then parallel the sequence of moves in an ultimatum game: the seller offers a discount of any desired size (including no discount at all). Once transmitted, the buyer responds by purchasing the unit at the discounted price (by pressing "p") or by shopping elsewhere (by pressing "s"). Since negotiations are conducted sequentially, this procedure is relatively slow. To prevent buyers with low time values from endlessly rotating among the sellers until eliciting a sizable discount, we imposed a small cost of 10 cents for switching sellers.[13]

Procedures for the two-posting treatment deviate from the standard posted-offer market in that after the initial price-posting and shopping sequence in each period, sellers are given a second opportunity to sell unsold units via a second price posting. Following the second posting, buyers are once again randomly selected to shop, and make as many purchases as desired at the posted prices. These procedures parallel those described by Mestelman and Welland (1993), except that, as in the other sessions, buyers pay a 10-cent fee each time they changed sellers.

Finally, the excess-demand-revelation treatment was administered as a standard posted-offer market, except that at the beginning of each period buyers indicated "intended purchases," or the maximum number of units they would purchase from the seller posting the lowest price. When the low-pricing seller sold all his or her offered units, all buyers who had either not yet

---

[12] Our posted-offer markets differ from the standard described in the text only in the respect that buyers are charged 10 cents each time they switch from one seller to another in a trading period. This shopping cost is necessary in the treatment with discounts, and was included in the baseline posted-offer sessions for purposes of comparability.

[13] There are other ways to speed up procedures when negotiations are possible. For example, Plott and Wilde (1982) let everyone negotiate at once, but then closed the market at a prespecified time. Our switching- cost approach is rather novel, and is interesting in its own right. Extensions of it would allow examination of predictions from the search and switching cost literatures.

Table 2. Mean absolute price deviations and efficiencies.

Session	Mean Absolute Price Deviation	Efficiency
PO1	36	57
PO2	32	57
PO3	36	38
Posted Offer Average	**35**	**51**
LD1	31	67
LD2	31	80
LD3	30	60
List Discount Average	**31**	**69**
2P1	38	65
2P2	28	68
2P3	14	66
Two-Posting Average	**27**	**66**
ED1	32	61
ED2	36	61
ED3	15	58
Excess Demand Revelation Average	**28**	**60**

shopped, or who were in the shopping process recorded intended purchase information for the seller posting the next-lowest price. The process was repeated a third time for the high pricing seller, when the next-to-the-lowest price seller stocked out. To motivate buyers to be accurate in recording intended purchases, they were restricted from purchasing more than their revealed intended quantity. (Buyers could over-report demand. But over-reporting is generally against the buyers' interests, since, if anything, it would encourage sellers to raise prices. In any event, over-reporting was never observed, and buyers were almost uniformly fully revealing). Excess demand information was recorded privately, so that stock-outs were not public information, as is consistent with other treatments. Sellers were privately given the aggregated intended purchase information prior to posting prices in the subsequent period.

With the exception of the second round in the two-posting treatment, and potential sales information in the excess-demand-revelation treatment, all instructions, procedures and record keeping were computerized, using software for networked PC's written by Davis.[14] Participants were student volunteers recruited from principles and intermediate economics classes at the University of Virginia. No participant had previously participated in a market experiment, and nobody participated in more than one session. In addition to their earnings from trades, participants were paid $6.00 for meeting their appointment. Sessions lasted for two to two-and-one-half hours, and individual earnings ranged from $15.25 to $38.25.

The experiment design is summarized by the session identifiers printed in the left column of table 2. Each session is described by a letter denoting the trading institution ("PO" for posted offer, "LD" for list discount, "2P" for two posting, and "ED" for excess demand revelation), and its number in sequence (1, 2 or 3). Thus, for example, "PO1" denotes the first of the three posted offer sessions.

3. Results

Results are organized about four primary conclusions.

Conclusion 1: *The price-tracking and efficiency-extraction of response of posted-offer markets to demand shocks is poor. The poor response is not an artifact of design or procedural features such as the number of sellers, the use of simulated buyers or the presence of trading commissions.*

Support: This is simply a calibration result. The close relationship between results of our posted-offer markets and those reported by Davis, Harrison and Williams can be seen by comparing posted-offer results in table 2, with summary measures for the posted offer sessions

[14] Although instructions were fully automated, they were read aloud as participants followed along at their terminals. Reading appears to improve comprehension. A copy of the posted-offer instructions for this program appears in appendix A4.1 of Davis and Holt (1993b).

reported by Davis, Harrison and Williams in table 1. Both mean absolute price deviations and efficiencies are virtually identical in each design (35 cents vs. 37 cents, and 51% vs. 48%).

The similarity of results across the two studies is especially notable in light of the numerous procedural and design differences between them. For example, we used 3 rather than 4 agents on each side of the market, and we avoided the use of a 5-cent per trade sales commission, by inducing a 10-cent vertical overlap at each competitive equilibrium. Other procedural differences are our use of human rather than simulated buyers, and our use of inexperienced participants. Additionally, for purposes of comparability with the list-discount sessions, buyers in our posted-offer sessions were charged a 10-cent fee each time they switched from one seller to another. This comparability of results across designs motivates the second sentence of the conclusion. ■

The switching cost is a particularly novel feature of our design. The apparent absence of any effect in this context merits separate comment, which we offer without further support.[15]

> ***Comment:*** *In this context, the imposition of a 10-cent switching fee on buyers does not appear to affect market performance.*

Thus, as observed elsewhere, agents in the posted-offer markets have trouble responding to aggregate demand shifts. Sellers, who dictate proposed terms of trade, see only the price postings of the other sellers and their individual sales volume. This limited information provides only the crudest of clues regarding appropriate price adjustments. For example, although a period without sales suggests that a price decrease is in order, the appropriate size of the decrease is indeterminate. On the other hand, if all offered units sell, the ambiguity increases, since a stock-out may be an indication either of an equilibrium price or of excess demand of an unspecified magnitude.

The consequences of this informational problem are clear from inspection of the sequence

---

[15] However, due to the switching cost, efficiencies are not perfectly comparable across experiments. Switching costs deflate both the surplus extracted as well as the maximum available surplus: Formally, $E = \Sigma_j(\pi_j - sN_j)/J(\pi_{ej} - sN_{ej})$, where s is the switching cost, N_j denotes the number of switches made by buyers in period j, and N_{ej} is the minimum number of switches necessary for the buyers to extract all gains from trade in our markets. As a practical matter, the effects of this adjustment are trivial in the posted-offer markets, since both sN_j and sN_{ej} tended to equal 30 cents in each period (i.e., buyers each approached only a single seller, as is necessary in an efficient outcome.)

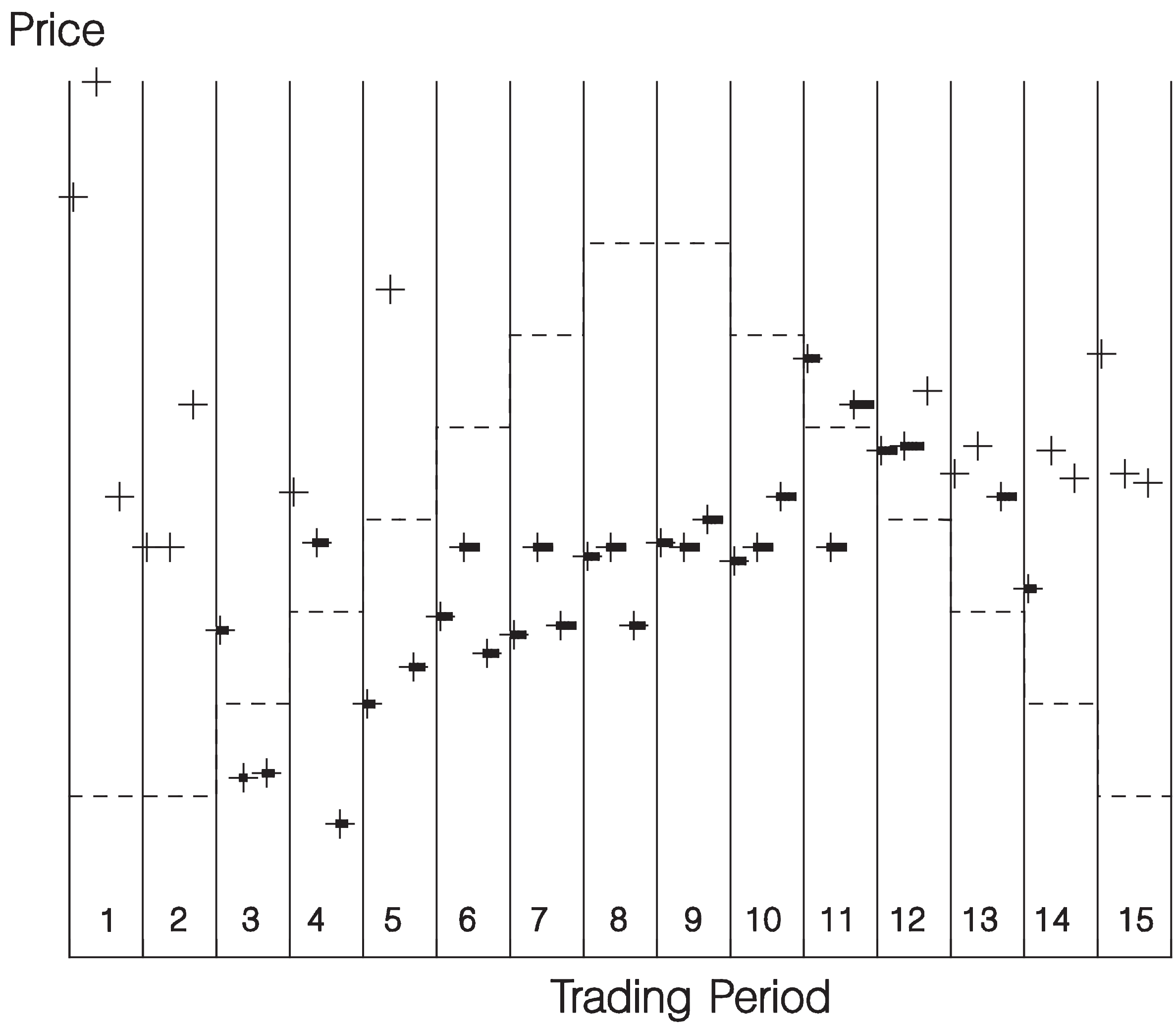

Figure 2. The sequence of contracts for session PO1. (Key: "+" = price postings, "▪" = contracts.)

of contracts for session PO1, in figure 2. In the figure, trading periods are illustrated as a numbered series of vertical strips running from left to right across the chart, while the midpoint of the underlying competitive equilibrium price for the period is shown as a dashed horizontal line. In early periods sellers not only overshot the competitive price range, but missed the market entirely, by posting prices (crosses) above any buyer's limit price. As indicated by the efficiency and sales volume numbers listed in the bottom of each trading-period stripe, this resulted in both volumes and efficiencies of 0. Sellers responded by lowering prices in period 2 and again in 3, until some units sold (indicated by dots extending from the center to the right of each price posting cross). Starting in period 6, the sellers began to sell all units offered each period, and they responded with cautious price increases. Prices drifted slowly upward, until crossing the market demand curve in period 11, at which time one seller (S1) failed to stock out. Posted prices leveled off, and then fell in periods 12 to 15. The reductions, however, were far less than the changes in the underlying equilibrium, resulting in progressive volume decreases and efficiency losses, capped by a complete market collapse in period 15.

Figure 3. Mean contract price paths for posted-offer, list-discount and clearance-sale sessions.

The mean transactions price paths for the 3 posted-offer sessions are plotted as solid, dashed, and dotted lines in upper left panel of figure 3. Line segments are started and ended with '■,' '*' and '+' symbols, respectively, and gaps in the lines indicate no trade. Session PO1 (illustrated by the solid curvilinear line) is representative. In each session, the mean contract price path altogether failed to track the underlying competitive price path.

Conclusion 2: *The opportunity for sellers to grant secret, selective discounts improves efficiency and price-tracking response. Nevertheless, price tracking remains poor and efficiency losses remain large.*

Support: The summary measures for the posted-offer and list-discount sessions in the top part of table 2 indicate the improvements in price-tracking and efficiency performance with discounting. Overall, the absolute mean price deviation decreases by 4 cents (from 35 to 31 cents). More substantially, mean efficiency measures increase by 19 percentage points (from 51% in the posted-offer sessions to 69% in the list-discount sessions). These improvements are statistically significant. In each case, let the null hypothesis be that a summary measure in the list-discount treatment is no different from the comparable measure in the posted-offer treatment. Using the nonparametric Mann-Whitney test, these hypotheses can be rejected at a 95% confidence level.[16]

The second, qualifying, sentence of conclusion 2 is apparent from a further inspection of table 2. Although significant, the performance improvements are relatively modest, particularly in price tracking. As is seen from examination of mean contract price paths for list-discount sessions, shown in the upper-right panel of figure 3, prices still largely fail to track the underlying competitive price path, again drifting up far more slowly than the underlying competitive equilibrium in inflationary periods, and falling only after the competitive equilibrium price crosses the mean contract price in the deflationary periods. Also, as indicated by the

---

[16] The test statistic of 21 exceeds the 95% critical value of 19. (For a description of the test, see Conover, 1980, p. 280). For the cases illustrated in the table, the intuition behind this result is straightforward. Consider efficiencies. Note that efficiency in each of the list-discount sessions is higher than in any of the posted-offer sessions. Of the C_3^6 = 20 possible rank order sequences possible for efficiencies in the 2 treatments, this is the most extreme. Under the null hypothesis that the groups are identical, this occurs with a probability p = .05. The null hypothesis of no difference in mean absolute price deviations is rejected by identical reasoning, since the largest of the deviations in the list-discount sessions is smaller than the smallest deviation in the posted-offer sessions.

truncation of the curvilinear price lines, sales volume slows or drops off altogether in the final periods of each session.[17] ■

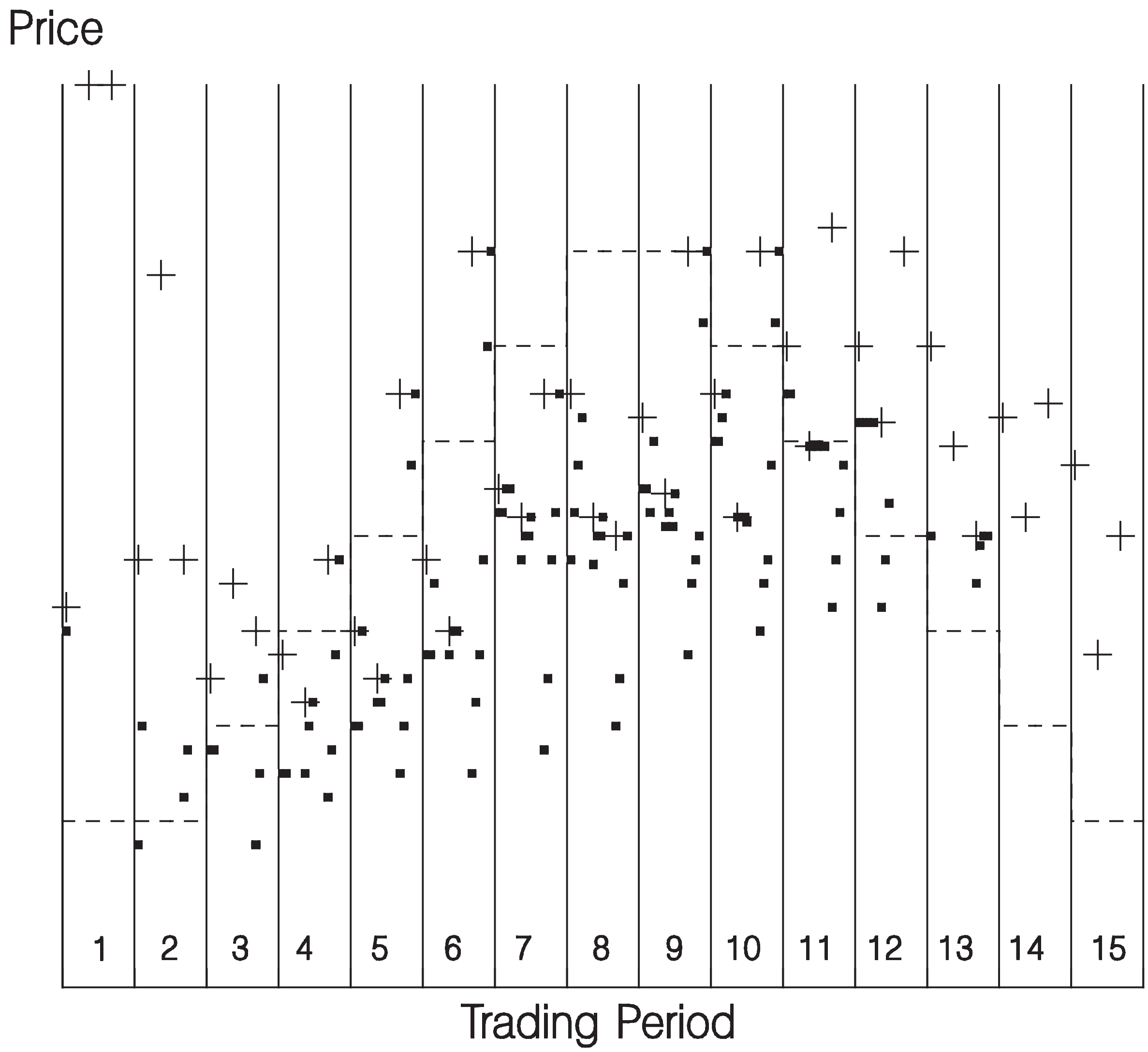

Figure 4. The sequence of contracts for session LD2. (Key: "+" = price posting; "■" = contract.)

Some insight into the relatively large improvement in efficiency, and the modest improvement in price tracking may be gained from inspection of the sequence of contracts for representative list-discount session LD3 in figure 4. The posted-price crosses in each period

---

[17] Recall, however, that the abbreviated price-path of session LD2 (indicated by the dotted-line) was caused by a time constraint. We were forced to truncate this session after period 13.

follow changes in the underlying competitive equilibrium with little more precision than in the posted-offer session illustrated in figure 2. Rather, as indicated by the "rain" of contract dots dripping below the price postings, the discounts improve efficiency by allowing the nervous sellers to revise their prices continually, given the postings and possible discounts of the others. As in the posted-offer markets, contract volume diminishes, and then drops off altogether when sellers' confidence that they can strike contracts at progressively higher transactions prices runs up against the underlying decrease in the capacity of buyers to purchase units.

Notice also that the efficiency gains are tempered by the extra shopping expenses incurred by the buyer. In period 2, for example, only 29% of the possible gains from exchange were extracted, despite the fact that 4 of the 5 contracts possible in this period were struck. Efficiencies became negative in periods 14 and 15 as buyers failed to make any purchases.

> ***Conclusion 3:*** *The opportunity for sellers to eliminate excess stocks through a second price-posting increases trading efficiencies. Efficiency losses, however, remain high, and price tracking, poor.*

Support: Comparison of efficiency measures for the two-posting markets in table 2 with comparable measures for the posted-offer sessions provides support for the first part of conclusion 3. As in the list-discount sessions, the two-posting mechanism increases efficiency extraction from roughly half of the possible surplus in the posted-offer sessions, to two-thirds of the possible surplus (51% to 66%). The null hypothesis that mean efficiencies in the two-posting treatment do not differ from those in the posted-offer sessions can be rejected at a 95% confidence level, using the Mann-Whitney test.[18]

No statistical result regarding price tracking relative to the posted-offer markets may be made, since pricing performance in the 2-posting markets was highly variable. As indicated by the mean absolute price deviations for the 2-posting markets in table 2, the absolute price deviation was higher in one of the 2-posting sessions than in any of the posted offer sessions (2P1, 38 cents), and smaller in the other two sessions, with particularly small deviations observed

---

[18] As for the tests in note 16, the relevant test statistic is 21, which exceeds the critical value of 19 for a 95% confidence level.

in session 2P3.

The second, qualifying sentence of the support also follows directly from the summary measure printed in the table. Mean efficiencies of 66% are far from perfect. Similarly, as is clear from inspection of the mean transactions price paths for the two-posting sessions, in the lower-left panel of figure 3, a second price-posting opportunity does not eliminate price rigidities found in the posted offer markets. ■

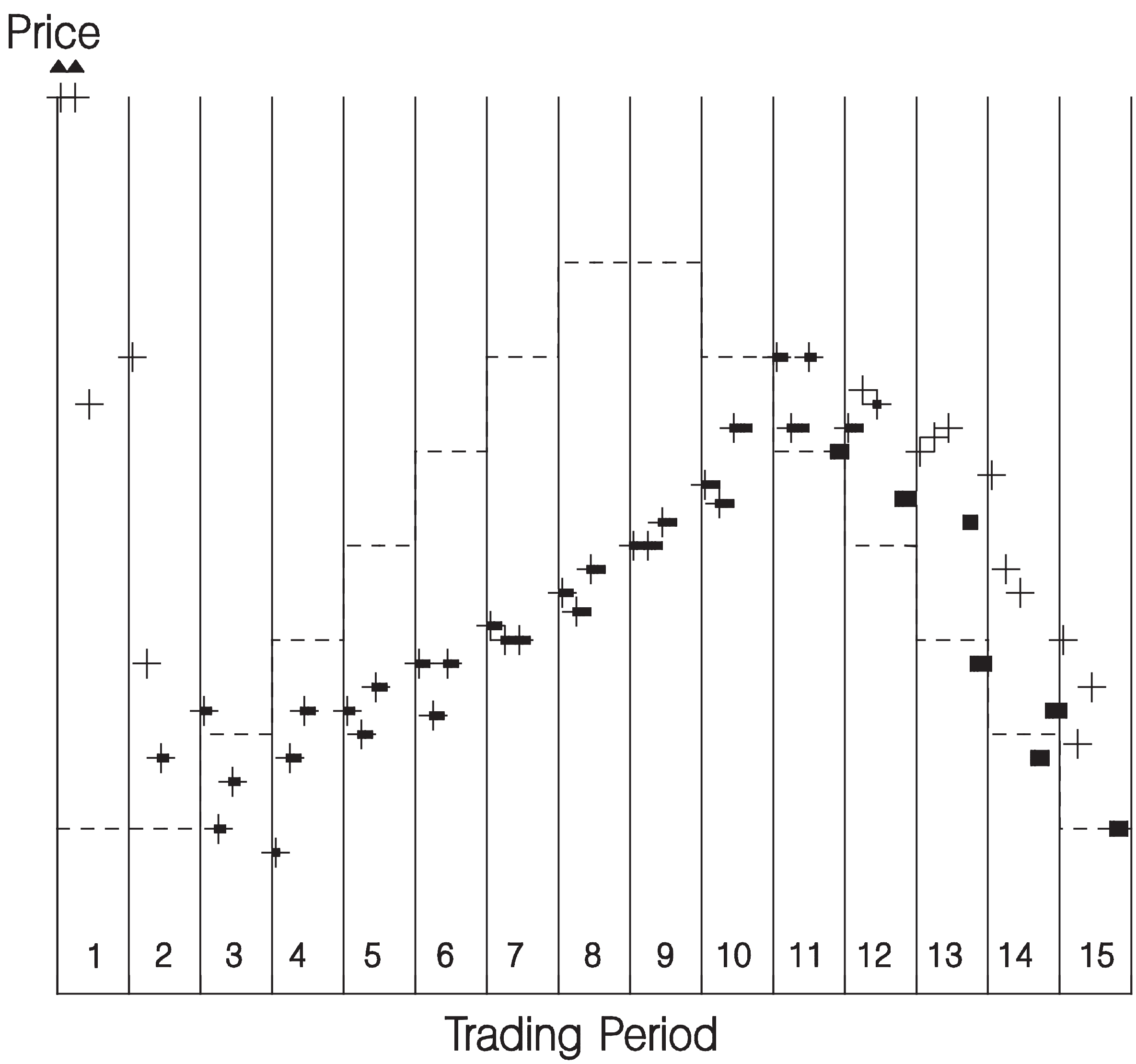

Figure 5. The Sequence of contracts for session CS2. (Key: "+" price postings, "▪" contracts at original posted prices; " ■" contracts at second posted price.)

For the purpose of gaining some insight into the reasons underlying the relatively modest improvements generated by a second price posting, it is useful to consider the sequence of contracts for session 2P2, is shown in figure 5.[19] This chart is formatted in the same manner as the sequences in figures 2 and 4, except that contracts arising from a second posting are denoted by the bolded squares in the right portion of each period-stripe. Importantly, contracts due to second postings occurred only in deflationary periods 11 to 15. In addition to periods 11 to 15, secondary postings occurred only in periods 1 and 2 of this market. No contracts from secondary postings occurred in these periods since, except for the initial posting of seller 3 in period 2, both the initial and secondary postings exceeded the upper limits of the demand curve. Prices look much like those in a typical posted-offer session throughout periods 3 to 10, with buyers exhausting supply each period, and prices slowly creeping upward. Both the period-by-period efficiencies and sales volumes are similar to those for session PO1 in figure 2.

Results of this session provide a ready rationalization for the modesty of the observed performance improvements: Our implementation of the two-posting mechanism allows some possibility for improvement in a deflationary regime, but not in an inflationary regime. When the underlying equilibrium price is falling, any seller posting a second price provides public information to the other sellers that their initial posted price was too high. If all sellers submit a second posting at the end of a period, it is common knowledge that even the lowest of the initial prices was too high.[20] There is nothing in this modified environment, however, that allows information regarding the magnitude of excess demand to be conveyed. For this reason, there is little reason to expect price-tracking improvements in inflationary periods.[21, 22]

---

[19] The mean contract price path for this session is illustrated by the solid line in the lower left panel in figure 3. As suggested by the relative location of that line, this session was chosen for discussion, since it was an intermediate result.

[20] Nevertheless, the asymmetry of buyers' and sellers' actions remains in this environment. Although sellers have an increased opportunity to respond to overly high prices, their information about the magnitude of their initial pricing errors is not particularly accurate, and they may largely miss the market, as occurred in periods 1, 2 and 15 of session 2P2.

[21] In addition to the informational problems, the inability of sellers to revise prices upward as well as downward within a period is an impediment to fluid responses in an inflationary regime. Although we do not examine an institution that allows upward price revisions here, it certainly merits investigation. One possible way to proceed might be to allow sellers to "test the water" at the beginning of a period by offering a small quantity at a trial price. Then, after all buyers had an initial opportunity to respond, sellers could make a second price and quantity decision.

A final question then regards the effects of explicitly providing sellers with excess demand information. Telling sellers how many units they could have sold at a given price should improve performance in inflationary periods. In a deflationary regime, sellers already know that they have posted a price that is too high, and that a downward adjustment is in order. However, in inflationary periods, the only way to be certain that an upward adjustment is appropriate is to explicitly be given information regarding excess demand. In natural contexts, such information may be available in the form of queues for a product at existing prices, or, at a minimum, by customers asking for an item that is out of stock at a given price. We attempted to provide comparable information in the laboratory by eliciting maximum intended purchase information from the buyers who either had not shopped, or were in the process of shopping, as each new price became relevant.[23] As with the other institutional variations, the provision of this information elicited a treatment effect. The effect, however, was surprisingly small, and generally did little to improve price tracking, even in inflationary periods. Results of this treatment are summarized as:

> ***Conclusion 4:*** *Providing sellers information regarding excess demand modestly increases trading efficiencies. Efficiency losses, however, remain high, and price tracking poor.*

Support: As with the other institutional variations, support for the first part of conclusion 3 is provided by a comparison of efficiency measures for the excess demand revelation sessions in table 2 with comparable measures for the posted offer sessions. Mean efficiencies in excess

---

[22] Given the absence of any particular feature of the two-posting mechanism that indicates the magnitude of demand increases, the price-tracking response in session 2P3 is impressive. (The mean absolute price deviation in this session 14 cents). We attribute the observed performance to seller optimism in the inflationary periods, rather than to unusual intelligence or savvy, since performance for the session as a whole is less outstanding. As indicated in the bottom row of table 2, overall efficiency was not unusually high in this session. In large part, the efficiency losses occurred in latter periods because, even with two-postings, the sellers failed to cut prices sufficiently at the end of the deflationary sequence. These errors do not inflate the mean-absolute-price deviation, since no contracts occurred in these periods.

[23] Another way to provide some excess demand information in the laboratory would be to allow sellers to publicly observe all sales. As mentioned in note 9, this information is routinely provided in some laboratory posted-offer implementations. We chose our approach, as it more closely parallels the type of information available to sellers in many posted-price markets. The methods, however, provide roughly comparable information, and the absence of a sizable treatment effect in our implementation makes us skeptical that publicly observing sales would markedly improve performance in this context.

demand revelation sessions ED1, ED2 and ED3 exceed those generated in the most efficient of the baseline sessions, which allows rejection of the null hypothesis that mean efficiencies in do not differ across the excess demand revelation treatment at a 95% confidence level, using the Mann-Whitney test.[24]

Two brief observations will suffice to support the second sentence of the conclusion. First, the improvement in efficiency performance is particularly modest in this context. Overall efficiency improves only about 9% over the baseline posted-offer sessions (from 51% to 60%), and efficiency in each of the excess demand revelation sessions is lower than in any of the 2-posting sessions, and in two of the three list-discount sessions.

Second, although the variability of pricing performance in the excess demand revelation sessions preclude the drawing of any statistical conclusion regarding price tracking performance, price tracking remains poor. As indicated by the mean absolute price deviations for the excess-demand revelation sessions, the absolute price deviation was substantially smaller in one of the sessions (ED3, 15 cents), but no different from the deviations observed in the baseline PO sessions in the other two sessions. ■

The sequence of contracts for representative session ED1, shown in figure 6, highlights the absence of a significant treatment effect:[25] both the attenuated ascent of prices during the inflationary periods, and the slow descent of prices after the underlying equilibrium passes the contract price path (along with the consequent drying up of contracts) compare favorably with the price pattern for session PO1 in figure 2.

Importantly, we cannot attribute the absence of a treatment effect to confusion among the sellers regarding the meaning of the excess demand information. After each session a monitor debriefed at least two of the three participant sellers. In response to the question "was the extra information useful," the debriefed participants uniformly indicated that it was useful, because it allowed them to know whether or not they could raise prices in the following period. Of course,

---

[24] As in notes 16 and 18, the relevant test statistic is 21, which exceeds the critical value of 19 for a 95% confidence level.

[25] The mean contract price path for this session is illustrated by the solid line in the bottom panel of figure 3. As in the other institutional treatments, this session is chosen for discussion as an intermediate result.

excess demand information does not suggest with any precision how much sellers may adjust prices. Turning back to the mean transactions price paths for the excess demand revelation sessions, shown in the bottom-right panel in figure 3, results in two of the three sessions suggest that seller responses tend to be overly conservative.

4. Parting Comments

The magnitude of the observed efficiency losses and price deviations in our treatment sessions deserves emphasis. Efficiency tends to be nearly 30 percentage points lower in any of our institutional variations than in comparable double auction sessions (summarized in table 1). Similarly, price deviations are twice as large on average in the modified sessions as in the double auctions. By the standards common to market experiments, these differences are huge.[26]

Of course, the modifications studied here are relatively modest deviations from standard posted-offer market rules. More elaborate variations are possible, and at some point these variations may eliminate the observed rigidities. For example, an n-posting mechanism that allows both for multiple price-postings, and for offer-quantity adjustments within a period, may track prices relatively well, particularly if sellers may revise prices both up and down in a period. These variations may have clear analogues in natural environments, and a critical behavioral question we have not succeeded in answering is what institutional adjustment(s) will be sufficient to allow individuals to distinguish randomness in their own experience from alterations in market fundamentals.

Nevertheless, the data reported here allow us to conclude that the answer to this question is not trivial. Further, we conjecture that, given some limitation on the flow of information, trading institutions where one side of the market dictates the terms of trade will tend to track prices poorly. Given the magnitude of the observed deviations, the clear lesson of this research

---

[26] For example, in a stable environment, Mestelman and Welland (1993) observe that 2 postings improve mean efficiency from 88% in 5 baseline posted-offer markets to nearly 94% in 5 treatment sessions. This compares to an efficiency average of 98% for 5 double-auction sessions. Mestelman and Welland did not provide sufficiently disaggregated data to allow calculation of mean absolute price deviations by session. Nevertheless, for some idea of typical price deviations in laboratory markets, note that using data aggregated across sessions, 2 postings reduced the mean absolute price deviation from 10 cents in baseline posted-offer markets to 4 cents. This compares to mean absolute deviations of 2 cents in their double-auction sessions.

is that a closer look into market interdependencies under various institutions is warranted.[27]

References

Clauser, Laura and Charles R. Plott (1991) "On the Anatomy of the 'Nonfacilitating' Features of the Double Auction Institution in Conspiratorial Markets," forthcoming in D. Friedman, S. Genakopolos, D. Lave, and J. Rust, eds., *Double Auction Market: Institutions, Theories, and Laboratory Evidence*, (Addison-Wesley, Reading).

Conover, W. J. (1980) *Practical Nonparametric Statistics* (John Wiley and Sons, New York).

Daniels, B.P. and Charles R. Plott (1988) "Inflation and Expectations in Experimental Markets," in R. Tietz, W. Albers and R. Selten, eds., *Bounded Rational Behavior in Experimental Games and Markets*, (Springer-Verlag, Berlin).

Davis, Douglas D., Glenn W. Harrison and Arlington W. Williams (1993) "The Effects of Nonstationarities on the Convergence to Competitive Equilibria," *Journal of Economic Behavior and Organization*, *20*, 1-22.

Davis, Douglas D., and Charles A. Holt (1993a) "Conspiracies and Secret Discounts in Laboratory Markets," working paper, University of Virginia.

Davis, Douglas D., and Charles A. Holt (1993b) *Experimental Economics* (Princeton University Press, Princeton).

Davis, Douglas D., and Arlington W. Williams (1991) "The Hayek Hypothesis in Experimental Auctions: Institutional Effects and Market Power," *Economic Inquiry*, *29*, 261-274.

Greenwald, Bruce, and Joseph Stiglitz (1993) "New and Old Keynesians," *Journal of Economic Perspectives*, *7*, 23-44.

Hong, James T. and Charles R. Plott (1982) "Rate Filing Policies for Inland Water Transportation: An Experimental Approach," *Bell Journal of Economics*, *13*, 1-19.

Isaac, R. Mark., Valerie Ramey, and Arlington W. Williams (1984) "The Effects of Market Organization on Conspiracies in Restraint of Trade," *Journal of Economic Behavior and Organization*, *5*, 191-222.

---

[27] One immediate extension would be to evaluate the effects of price posting in a simple macroeconomy, such as a variant of the environment reported by Lian and Plott (1993). As is clear from these authors' discussion of the difficult choices that must be made to construct a laboratory macroeconomy, this task is far from trivial.

Ketcham, Jon, Vernon L. Smith, and Arlington W. Williams (1984) "A Comparison of Posted-Offer and Double-Auction Pricing Institutions," *Review of Economic Studies, 51*, 595-614.

Lian, Peng and Charles R. Plott (1993) "General Equilibrium, Macroeconomics and Money in a Laboratory Experimental Environment," California Institute of Technology, Social Science Working Paper 842.

Mestelman, Stuart, and J. Douglas Welland (1993) "Price Flexibility and Market Performance in Experimental Markets," *Economic Theory*, forthcoming.

Plott, Charles R. (1986) "The Posted-Offer Trading Institution, *Science*, *232*, 732-738.

Plott, Charles R. and Louis Wilde (1982) "Professional Diagnosis vs. Self-Diagnosis: An Experimental Examination of Some Special Features of Markets with Uncertainty," in V. Smith, ed., *Research in Experimental Economics, vol.2,* (JAI Press, Greenwich Conn.) 63-112.

Rustichini, Aldo, and Anne P. Villamil (1992) "Equilibrium Price Stickiness," manuscript, University of Illinois.

Smith, Vernon L. (1981) An Empirical Study of Decentralized Institutions of Monopoly Restraint, in J. Quirk and G. Horwich, eds., *Essays in Contemporary Fields of Economics in Honor of E.T. Weiler, 1914-1979* (Purdue University Press, West Lafayette), 83-106.