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Money vs Gaming: Effects of Salient Monetary Payments in Double Oral Auctions

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The significance of using performance-based monetary rewards in laboratory experiments has been a subject of debate among experimental economists and psychologists. Empirical evidence presented in this paper suggests that payment of performance-based monetary rewards in double oral markets is not a necessary condition for convergence to equilibrium. However, such rewards do increase the reliability or reproductibility of laboratory results and, therefore, constitute a valuable, albeit expensive, research tool.

Experimental psychologists and economists differ in the emphasis they place on the significance of providing performance-based rewards to human subjects. Psychologists (e.g., Tversky & Kahneman, 1986) tend to assume that subjects provide truthful responses in experiments and therefore consider the provision of performance-based rewards unnecessary. Accordingly, they pay fixed sums to their subjects (in dollars or in course credits) without establishing an explicit link between the amount of payment and the subjects' performance. Economists (e.g., Smith, 1982), on the other hand, view the provision of performance-based rewards to be crucial for the validity and reliability of their experiments. Further, their rewards are almost always monetary.

Do performance-based monetary rewards have a significant impact on subject behavior? Wright and Aboul-Ezz (1988) observed significant effects of performance-contingent extrinsic incentives in individual tasks. However, prior research suggests that information processing depends on

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the nature of the task and is quite sensitive to seemingly minor variations (Einhorn and Hogarth, 1981). We therefore narrow the scope of our enquiry to: Do performance-based monetary rewards have a significant impact on the behavior of subjects in double oral *market* settings? Empirical evidence presented in this paper suggests an affirmative answer.

Smith (1976, 1982) identified saliency and dominance as two sufficient conditions required to attain control in experimental economies. The dominance condition is satisfied if rewards offered to the subjects are sufficiently large so that the satisfaction or dissatisfaction arising from the rewards dominates any preference they may have for other aspects of participating in the experiment such as gaming. Smith explicitly recognized the possibility that subjects may be driven by multiple motivations. By offering large enough rewards, the experimenter can be reasonably sure that it is these rewards, and not others, that motivate subjects' behavior.

Saliency of rewards refers to the existence of an explicit link (direct or indirect) between rewards and actions of subjects. No matter how large they are, if subjects do not believe that rewards are affected by their actions, they are not salient. Fixed or randomly determined sums (with a fixed probability distribution) are not salient rewards since they do not depend on the subjects' actions. Practically all experimental economies examined by economists use salient rewards to induce a predetermined set of preferences among the subjects.

If the dominance condition holds, saliency of rewards is sufficient to induce preferences; whether the latter is also necessary is an open question. If the observed behavior remains unaltered when rewards offered are not salient, our ability to draw inferences about economic theories from experimental observations in such environments may be attenuated. Behavior which is observable in the absence of salient rewards cannot be attributed to motivations induced by salient rewards. On the other hand, if withdrawal of salient rewards alters behavior in a given environment, we could reasonably conclude that saliency of rewards is a *necessary* and not a merely sufficient condition for controlled experimentation in that environment. The researcher will then be able to assert, with some confidence, that experimental findings are due to the explicitly induced values through the reward mechanism, and not due to some other uncontrolled preferences which subjects may have for gaming, competition, etc. For our initial exploration of saliency, we chose the setting of a double oral auction with fixed demand and supply functions and monetary rewards which were large enough to have a high chance at being dominant for the subjects who earned approximately 8 to 12 dollars on average for participation in the 45–60 min experiments. The actual payments de-

pended on the rules of individual experiments and on individual trader performance.

We are not aware of any prior experimental evidence on the saliency condition in a market environment. Smith (1962, 1976) reported weakening the dominance condition by asking the subjects to regard an experimental "point" as if it were real money. Since rewards (experimental points) were explicitly defined functions of actions of the subjects, the saliency condition was satisfied. The dominance condition was weakened to the extent that thinking of experimental points as if they were money provided a weaker motivational force than money itself could provide. Smith's results show that the absence of cash rewards does not necessarily hinder convergence of prices to proximate equilibrium, though sometimes convergence is not as precise as with cash rewards.

Smith (1962) suggests two types of dominance: 1) dominance related to the reward level associated with each particular message a subject can send and 2) dominance related to rewards associated with generic behavior. The first of these depends on the reward being salient, while the second involves a nonsalient reward. Kormendi and Plott (1980) replaced monetary rewards by course grades and observed that the behavior remained essentially unaltered. Apparently, the dominance condition can be met by means other than monetary reward, and the latter is not necessary to establish experimental control.

RESEARCH DESIGN

While saliency of rewards is the treatment variable of interest in our research design, two other variables are also included. Prior research suggests that the behavior of markets is affected by the number of active traders (size) as well as by the prior trading experience the subjects have (experience).[1] In order to examine their effects, we manipulate saliency, experience and size of the market both within and between subjects in a series of six experiments. The complete design is shown in Table 1.

Subjects

Student volunteers for each experiment were recruited from introductory classes on English literature, history, political science, and sociology at the University of Minnesota. Subjects had not taken any courses on economics, finance, or business management. Most experiments included

[1] In order to maintain roughly the same range for demand and supply functions across experiments, increase in the number of traders is accompanied by a decrease in the size of steps in demand and supply functions. Within the context of our research design, these two types of size effects are not distinguishable from each other.

TABLE 1
DESIGN OF MARKETS

	Size (No. of active traders)			
	Large (8)		Small (4)	
	Fixed payment	Salient payment	Fixed payment	Salient payment
Inexperienced subjects	Markets 2B and 4	Market 2A	Markets 1A and 5	Market 1B
Experienced subjects	Markets 3A and 3C	Market 3B	Market 6A	Market 6B

subjects drawn from two or more classes. There was no attempt to gather subjects with identical majors into an experiment.

Experimental Procedure

Subjects were randomly assigned to two subgroups—buyers and sellers. Each buyer received a card containing a number, known only to that buyer, which represented the redemption value for each unit of the commodity traded. Each buyer was to earn points equal to the difference between his/her redemption value and the price at which he/she bought the commodity. No points were earned if the buyer did not buy a unit of the commodity. The redemption values induced a market demand curve which defines the set of possible demand quantities at each hypothetical price.

Each seller received a card containing a number, known only to the seller, which represented the cost of each unit of the traded commodity. Each seller was to earn points equal to the excess of his sale price over his cost. These costs generate a market supply curve which defines the set of possible supply quantities at each hypothetical price.

Each buyer and seller was allowed to conduct up to two contracts, each for the exchange of one unit, during each market period. Each experiment was conducted over a sequence of trading periods which were 4 min long.

A training exercise was conducted to familiarize the subjects with the experimental procedures and record keeping. The procedures used were similar to those used by Smith (1962, 1964), and are summarized below:

> The market opens for Trading in Period 1. This means that any buyer (or seller) is free at anytime to raise his hand and make a verbal offer to buy (sell) at any price which does not violate his maximum (minimum) reservation price. Any seller (or buyer) is free to accept a bid (or offer) in which case a binding contract has been cleared. As soon as a buyer/seller has completed two transactions he drops out of

the market in the sense of no longer being permitted to make bids, offers or contracts for the remainder of the market period. After four minutes the market is officially closed. This ends Period 1.

The market is then immediately reopened for Period 2. All buyers and sellers can again complete up to two transactions under the same price conditions as prevailed in Period 1. The same procedure is repeated in Period 3 and so on until the end of the experiment.

The demand and supply schedules for the six experiments reported in this paper are shown in Fig. 1.

RESULTS

We present experimental results in two steps. In the first step, we describe the findings of each of the six experiments and, in the second, analysis of covariance for coefficients of convergence for the entire dataset is presented.

Experiment 1

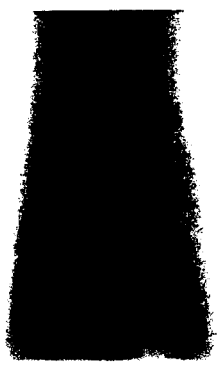
None of the eight student volunteers had previously participated in a market experiment (inexperienced subjects). Reservation prices given to the participants (four buyers and four sellers) yielded the supply and demand functions shown in the first illustration in Fig. 1. Equilibrium price was 350, equilibrium quantity was 2–4 units, and only four out of eight traders would have traded in equilibrium.

In the first five periods (Market 1A), subjects were given a fixed payment of $1 per period for participation in the experiment. During Periods 6–9 (Market 1B), subjects were paid based on the number of points earned ($.02 per point).

The price and quantity at which the supply and demand schedules intersect are the equilibrium price and quantity for the corresponding experimental market, though such an equilibrium will not necessarily be attained or approached in the market.

To estimate the tendency of transaction prices to converge to the predicted equilibrium price, a Coefficient of Convergence (CoC), α, has been computed for each trading period in each market. It is the ratio of the root mean squared deviation of exchange prices from the predicted equilibrium price, σ_o, to the predicted equilibrium price, P_o, expressed as a percentage: $\alpha = 100\ \sigma_o/P_o$.

As can be seen from the graph in Fig. 2 and the top panel of Table 2, Markets 1A and 1B differ substantially with respect to their CoC. Market 1A, where the participants were paid a fixed payment, did not converge toward the equilibrium price. However, Market 1B, where subjects were paid on the basis of their performance, shows strong convergence of price to equilibrium. Furthermore, trading volume drops from an average of 3.2



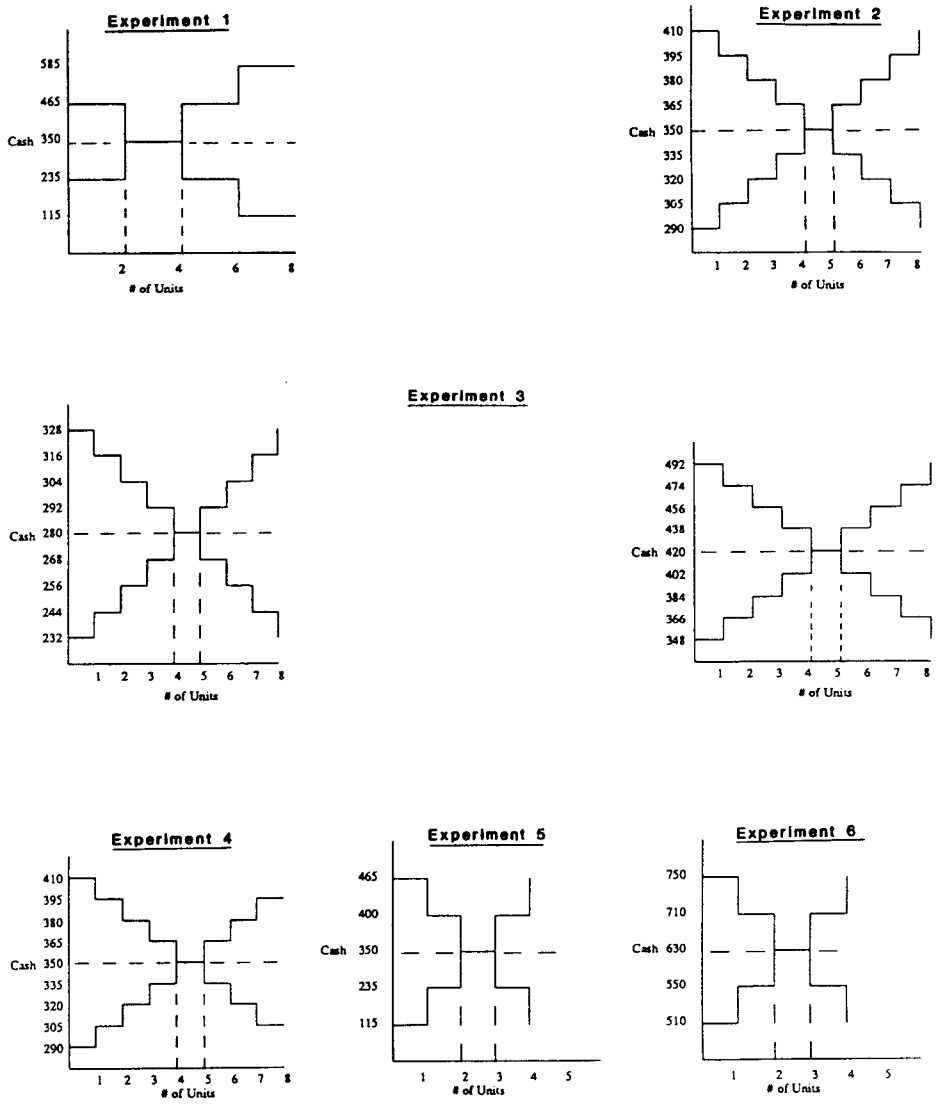


FIG. 1. Demand/supply schedules.

per period to 2. Apparently, subjects are willing to trade at zero, even negative, points only as long as the mode of payment remains fixed. A switch to salient payments brings an immediate halt to trades that make no points or lose points. The data indicate that the form of the payment (salient vs fixed) has a significant impact on performance in this market.

One major objection that can be raised regarding the comparison made

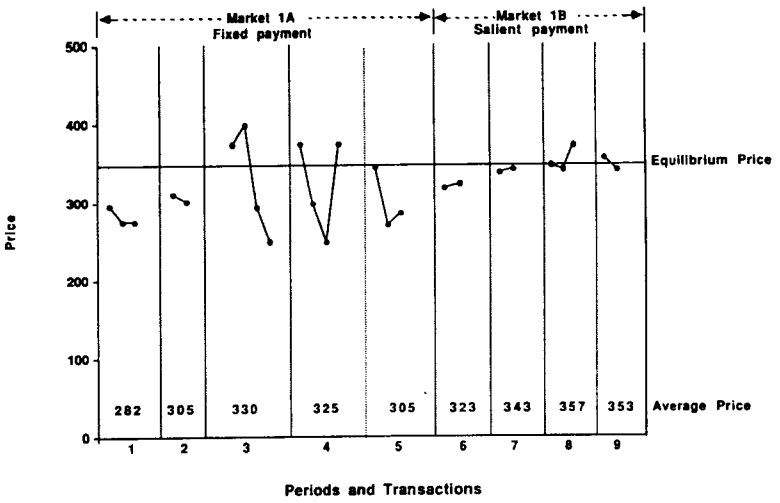


FIG. 2. Market 1. Subjects had no prior trading experience. Small size (four active traders).

above is that subjects in Market 1A were inexperienced whereas subjects in Market 1B had learned from their performance in Market 1A and hence were experienced. In order to untangle the effect of experience, Experiment 2 was carried out.

Experiment 2

Eight student volunteers were recruited from English literature classes. None of the subjects had participated in a previous market experiment (inexperienced subjects). All eight subjects (four buyers and four sellers) could trade in equilibrium.

In the first five periods (Market 2A), subjects were paid based on the number of points earned ($.01 per point). For Periods 6–10 (Market 2B), subjects were paid a fixed payment of $1.00 per period for participation in the experiment. Equilibrium prices and results are shown in Fig. 3 and the middle panel of Table 2.

As can be seen from Fig. 3 and the coefficient of convergence in Table 2, both Markets 2A and 2B converged towards the equilibrium price. A comparison of the results in Markets 1A and 2A shows that for inexperienced subjects payment based on performance led to a significantly better performance of the market. A comparison of the results in Markets 2A and 2B shows that the market did not deviate away from equilibrium behavior within 5 periods it was operated on fixed payments. The gaming aspect of the task seems to have been sufficient to keep the subjects interested during the last five periods of the experiment.

TABLE 2

Experiment	Trading period	Predicted quantity	Actual exchange quantity	Predicted exchange price	Average actual exchange price	Coefficient of convergence $\alpha = (100\ \sigma_o/p_o)$
1A (Fixed payment)	1	2–4	3	350	282	24.138
	2	2–4	2	350	305	18.29
	3	2–4	4	350	330	20.96
	4	2–4	4	350	325	19.34
	5	2–4	3	350	305	19.40
1B (Salient payment)	6	2–4	2	350	323	11.15
	7	2–4	2	350	343	3.194
	8	2–4	3	350	357	5.34
	9	2–4	2	350	353	3.194
2A (Salient payment)	1	4–5	4	350	368	8.57
	2	4–5	4	350	360	3.49
	3	4–5	4	350	361	5.01
	4	4–5	4	350	364	4.73
	5	4–5	5	350	361	5.0
2B (Fixed payment)	6	4–5	4	350	356	2.47
	7	4–5	5	350	365	5.39
	8	4–5	5	350	360	4.16
	9	4–5	5	350	360	3.91
	10	4–5	4	350	363	4.20
3A (Fixed payment)	1	4–5	5	280	267	9.149
	2	4–5	4	280	278	7.57
	3	4–5	4	280	288	6.19
	4	4–5	4	280	291	5.15
	5	4–5	5	280	282	4.37
3B (Salient payment)	6	4–5	4	280	288	3.57
	7	4–5	4	280	289	3.71
	8	4–5	5	280	285	3.85
3C (Fixed payment)	9	4–5	5	420	393	7.47
	10	4–5	4	420	414	2.28
	11	4–5	4	420	419	.69
	12	4–5	4	420	419	.41
4 (Fixed payment)	1	4–5	4	350	343	2.86
	2	4–5	4	350	345	2.33
	3	4–5	5	350	350	1.01
	4	4–5	4	350	346	1.51
	5	4–5	5	350	347	1.34
	6	4–5	5	350	349	1.23
	7	4–5	4	350	348	.68
	8	4–5	4	350	346	1.79
	9	4–5	4	350	345	1.57
5 (Fixed payment)	1	2–3	2	350	208	43.90
	2	2–3	2	350	260	25.75
	3	2–3	2	350	255	27.18
	4	2–3	3	350	293	23.96

TABLE 2—*Continued*

Experiment	Trading period	Predicted quantity	Actual exchange quantity	Predicted exchange price	Average actual exchange price	Coefficient of convergence $\alpha = (100\ \sigma_0/p_0)$
	5	2–3	2	350	273	22.15
	6	2–3	3	350	330	15.29
	7	2–3	2	350	278	20.72
	8	2–3	2	350	295	15.77
	9	2–3	2	350	305	12.93
	10	2–3	2	350	313	11.82
6A (Fixed payment)	1	2–3	2	630	613	3.41
	2	2–3	2	630	613	2.80
	3	2–3	2	630	623	1.68
	4	2–3	3	630	628	2.51
	5	2–3	2	630	625	.79
	6	2–3	3	630	628	.79
6B (Salient payment)	7	2–3	2	630	630	0
	8	2–3	1	630	630	0
	9	2–3	2	630	620	.70
	10	2–3	2	630	630	0
	11	2–3	2	630	625	.79

Experiments 1 and 2 seem to indicate that salient payments are necessary for markets to converge towards the equilibrium price. However, once subjects have learned what price range to expect, the gaming may be sufficient to yield the equilibrium price. Experiments 3–6 were conducted to test for the robustness of these findings.

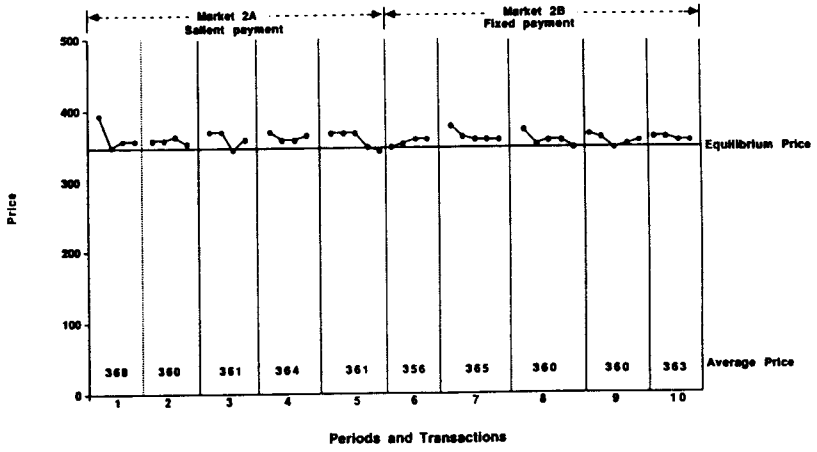


FIG. 3. Market 2. Subjects had no prior trading experience. Large size (eight active traders).

Experiment 3

Eight subjects who had participated in either Experiment 1 or 2 within the preceding two weeks were recruited to take part in Experiment 3 (experienced subjects). All eight subjects (four buyers and four sellers) were able to trade in equilibrium. In the first five periods (Market 3A), subjects were paid a fixed sum of $.60 per period for participation in the experiment. For the next three periods (numbered 6–8) subjects were paid $.02 for each point earned from trading in the market (Market 3B). After the eighth period, a new set of cards was distributed. Two illustrations for Experiment 3 in Fig. 4 show the supply and demand functions and equilibria before and after this change. For Periods 8–12 (Market 3C), subjects were paid a fixed payment of $.60 per period. Transaction prices converged to proximate equilibrium in all three parts of this experiment. These findings provide further evidence that once the subjects have learned how to perform in this market they do not necessarily deviate from equilibrium. Even when the reservation prices and market equilibrium was changed, they were able to rapidly adjust to the new equilibrium. Absence of salient payments did not keep them from adjusting to the new equilibrium.

Experiment 4

Eight student volunteers in this experiment were recruited from political science classes at the University of Minnesota. None of the subjects had previously participated in a market experiment (inexperienced sub-

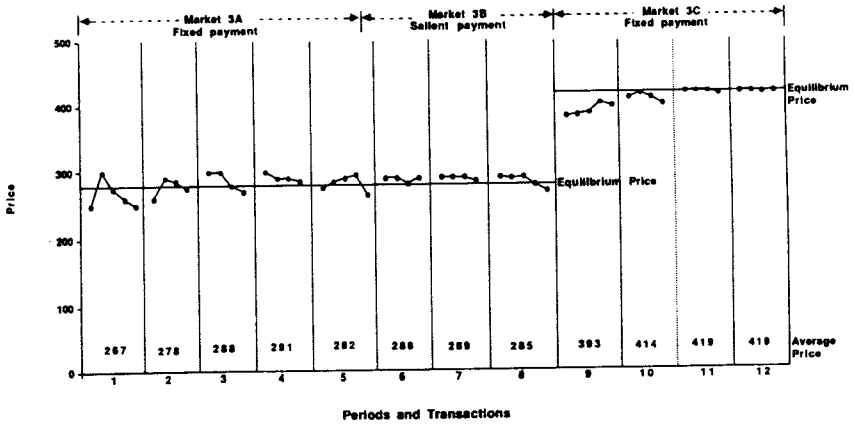


FIG. 4. Market 3. Subjects had prior experience in Market 1 or 2. Large size (eight active traders).

jects). All eight subjects (four buyers and four sellers) were able to trade in equilibrium. Subjects were paid a fixed payment of $1.00 per period for participating in each of the 9 periods of the experiment.

As can be seen from prices in Fig. 5 and the Coefficient of Convergence in Table 2, market prices converged rapidly toward the equilibrium level and stayed there over replications. The results are stable for the 9 periods even though payments are not salient. This behavior, with eight subjects, is quite different from the behavior of Market 1A which had only 4 active subjects.

Experiment 5

Four inexperienced student volunteers were recruited from history and sociology classes at the University of Minnesota. All four subjects (two buyers and two sellers) were able to trade in equilibrium. Subjects were paid a fixed fee of $1.00 per period for participating in each of the 10 periods.

As can be seen from Fig. 6 and Table 2, the market did not converge to the predicted equilibrium price. The equilibrium price of 350 is substantially different from the range in which trading took place (280–310). Experiment 5 replicated the results obtained in Experiment 1A where the market also failed to converge to the predicted equilibrium. In the absence of salient rewards, markets composed of a small number of inexperienced subjects do not converge to the economic equilibrium.

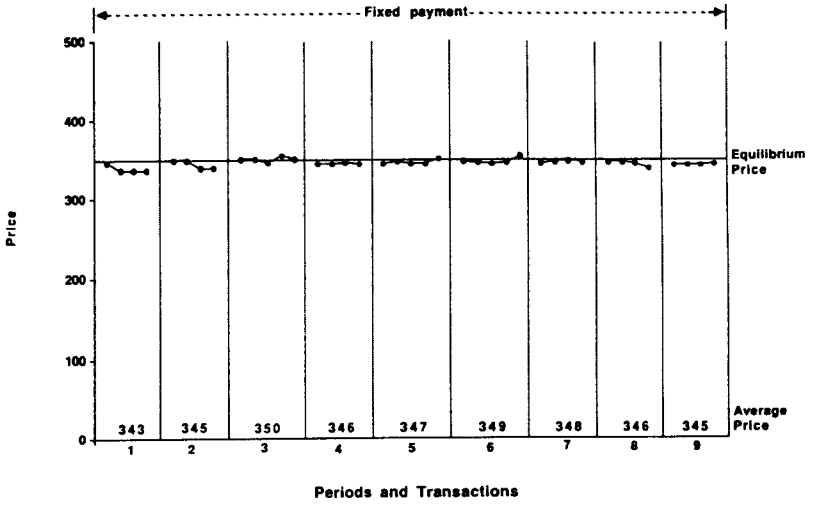


FIG. 5. Market 4. Subjects had no prior trading experience. Small size (eight active traders).

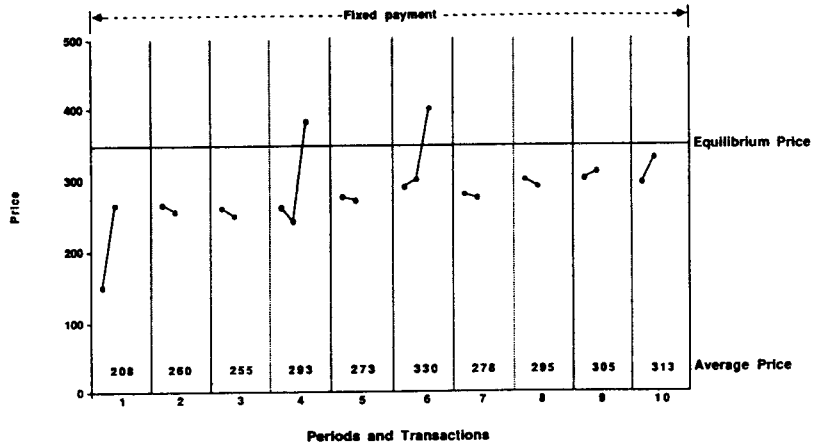


FIG. 6. Market 5. Subjects had no prior trading experience. Small size (four active traders).

Experiment 6

All subjects who took part in Experiment 5 took part in Experiment 6 which was conducted 2 days later (experienced subjects). During Period 1–6 (Market 6A) subjects were paid a fixed payment of $1.00 per period. During Periods 7–11 (Market 6B) subjects were paid $.01 per point.

As can be seen from Fig. 7 and Table 2, transaction prices in both Markets 6A and 6B converged to proximate equilibrium price. A comparison of the results for Experiments 5 and 6 shows that even when there

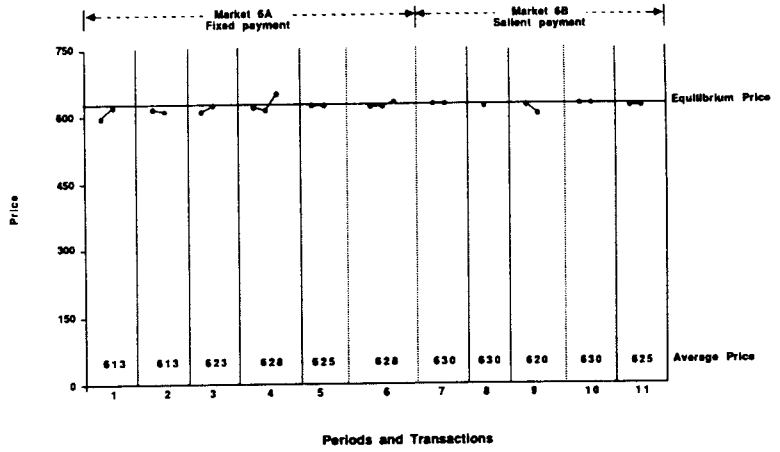


FIG. 7. Market 6. Subjects had prior experience in Market 5. Small size (four active traders).

are very few traders, experienced subjects are able to reach the economic equilibrium price. However, results from Experiment 5 where subjects are inexperienced and paid a fixed payment suggest that markets do not converge reliably in the absence of salient rewards.

Statistical Analysis

An analysis of covariance was carried out on the coefficients of convergence calculated for all six experiments reported in the paper. Main effects for form of payment (salient vs fixed wage), size of market (eight vs four active traders) and experience of subjects (the number of periods of prior experience) are all statistically significant at the .01 level. The analysis of covariance results are shown in Table 3.

The overall R^2 of 0.53 is significant at a $p < .01$. A plot of the coefficient of convergence across markets is shown in Fig. 8. A review of Fig. 8 shows that markets with salient payments have a smaller coefficient of convergence than fixed wage markets. In a similar manner, large size markets and markets with more experienced subjects have a much smaller coefficient of convergence. The experience and market size variable each explain three times as much variance as the mode of payment does.

The statistical analysis provides strong support for our discussion of results given above.

SUMMARY AND CONCLUSION

The results of this study have distinct, though complementary, implications for experimental psychology and economics. The fact that double oral auction markets can sometimes converge to equilibrium in the absence of performance-based rewards points to the importance of preferences for gaming in market settings. The results support Smith's emphasis on saliency and dominance of the reward function in designing experiments to conduct laboratory tests of economic theory. These conclusions

TABLE 3
ANALYSIS OF COVARIANCE FOR COEFFICIENT OF CONVERGENCE (α)

Source	Df	Sum of squares	Mean square	F value	$p_r > F$
Payment	1	396.145	396.145	9.94	0.0026
Size	1	1088.070	1088.070	27.32	0.0001
Experience	1	1089.571	1089.571	27.35	0.0001
Error	57	2270.530	39.833		
Total	60	4844.316			

Note. Payment = fixed or salient; Size = small or large; Experience = number of prior periods of participation.

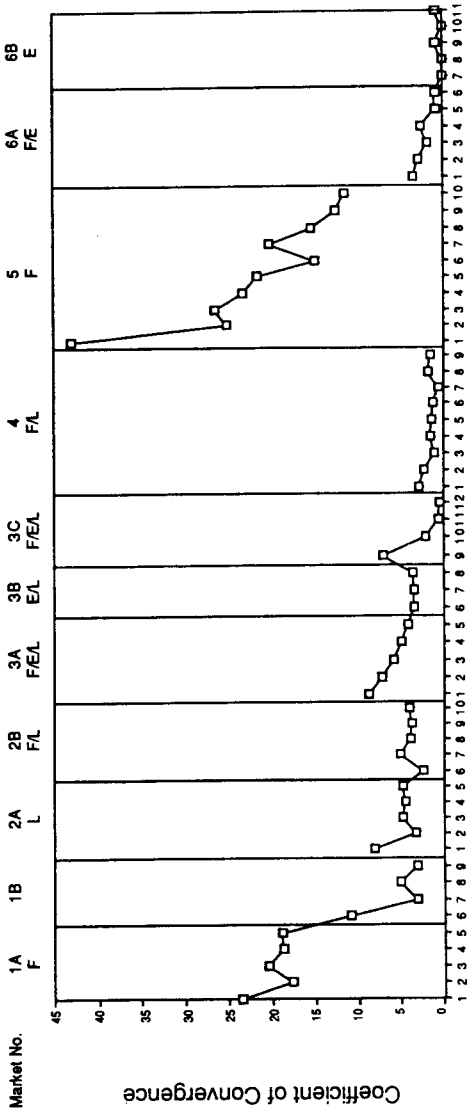


FIG. 8. Coefficient of convergence = (root mean squared deviation from equilibrium price)/(equilibrium price). F, fixed wage condition; E, prior trading experience; L, large size (eight active traders).

are reinforced by the findings that 1) in the absence of prior experience with performance-based rewards, market behavior does not reliably converge to economic equilibrium, and 2) in presence of performance-based rewards, it does so in all cases examined.

The results also suggest that in the absence of performance-based rewards, it is possible, or at least easier, for subjects who have had prior experience with the task in an environment of performance-based rewards, to act *as if* performance-based rewards are still in force. Sometimes experiments are conducted with expert subjects who are experienced in the type of task, but it is difficult to offer them meaningful performance-based rewards to fulfill the conditions of saliency and dominance. The ability of experienced subjects to act on an *as if* basis in the experiments reported here suggests the possibility that some inference from such experiments may be possible; the provision of performance-based rewards will, of course, make such inferences more reliable.

It may well be the case that we need to separate the issue of competence (learning) from the issue of performance. Research in psychology (Bidodeau, 1969) shows that learning can take place due to information feedback in environments without salient rewards. In a market environment, subjects get feedback in terms of observing bids, offers, and transactions taking place. However, in a market, we are not directly testing what people have learned. We infer what subjects have learned by looking at their performance on a task. In some cases the gaming utility may be sufficient to induce subjects to exhibit what they have learned; but in order to get reliable results, that is, induce all groups of subjects, we have to provide performance-based rewards. The results of Experiments 3, 4, and 6 suggest that subjects sometimes use what they have learned even without the provision of performance-based rewards. However, Experiments 1 and 5 suggest that sometimes subjects either may not learn, or may not show in their performance what they have learned, unless they have some incentive to do so. Generalizability of our double oral auction results to other trading institutions and nonmarket environments remains an open question.

Psychologists sometimes consider the provision of performance-based rewards to be unnecessary while economists tend to place little faith in results obtained from experiments without such rewards. The results of our experiments provide *some* support for both views. Apparently there is a rich middle ground between the two disciplines that can and should be explored further.

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