CONSIDERATIONS OF FAIRNESS AND STRATEGY: EXPERIMENTAL DATA FROM SEQUENTIAL GAMES*

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Laboratory data from bargaining experiments have started a debate about the prospects for various parts of game theory as *descriptive* theories of observable behavior, and about whether, to what extent, and how a successful descriptive theory must take into account peoples' perceptions of "fairness." Plausible explanations of the observed bargaining phenomena advanced by different investigators lead to markedly different predictions about what should be observed in three different games. A sharp experimental test is thus possible on this class of games, and the present paper reports the results of such a test.

I. INTRODUCTION

In recent years experimental evidence has started a debate about the prospects for various parts of game theory as *descriptive* theories of observable behavior, and about whether, to what extent, and how a successful descriptive theory must take into account peoples' perceptions of "fairness." These are questions that may eventually have very different answers in different domains of application, as well as for different parts of game theory.

For a simple class of sequential bargaining games, the evidence available to date has permitted different investigators to draw almost opposite conclusions. Some authors have concluded that game theory is without descriptive power, particularly when equilibrium predictions call for very unequal payoffs to the bargainers, and that a descriptive theory of behavior in games of this sort must essentially *be* a theory of what constitutes fair distributions of income. Other authors, viewing data from similar games, have concluded that with appropriate experience in suitable environments, subjects will quickly come to behave according to the straightforward predictions of subgame perfect equilibrium. In this view, the phenomena that the first group of authors attribute to subjects' considerations of fairness can instead be largely

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attributed to inexperience. A summary of some of the high points of this debate[1] is contained in the paper by Ochs and Roth [1989].

The hypotheses put forward on both sides of this debate can be viewed as sequential in nature. For example, Guth and Tietz [1988] have suggested that if the equilibrium of a game involves divisions that are too extreme, strategic considerations will be displaced by considerations of fairness.[2] On the other hand, explanations based on experience see elementary considerations of fairness being displaced by more strategic considerations as experience and understanding are acquired.[3]

Some recent experimental results reported by Harrison and Hirshleifer [1989] as part of an investigation concerned, not with bargaining, but with mechanisms for the provision of public goods, nevertheless present the opportunity to make a fairly sharp experimental test of how considerations of fairness and strategy interact in bargaining.[4] The reason is that the "best-shot" games which they study (to be described below) have essentially the same perfect equilibrium behavior as "ultimatum" bargaining games (also described below) but give players very different incentives *off the equilibrium path.* And the experimentally observed behavior reported for the two kinds of games are very different: Harrison and Hirshleifer report observations very near the perfect equilibrium predictions, which give the players very unequal distributions of income, while ultimatum bargaining games have been robustly observed in many experiments to yield much more equal distributions of income. So one hypothesis is that the difference in the observed behavior has to do with the strategic differences between the two games.

But Harrison and Hirshleifer's experiments were conducted under conditions in which subjects were not informed of one another's payoffs, so another hypothesis is that the difference in observed behavior is due to the fact that they were not able to

1. See Guth, Schmittberger, and Schwarz [1982]; Binmore, Shaked, and Sutton [1985, 1988]; Neelin, Sonnenschein, and Spiegel [1988].

2. It has further been suggested that subjects' perceptions of fairness draw on social norms that are themselves accessed hierarchically, with some rules of division replacing others in those situations in which sufficient information is available to the players about one another's payoffs. For example, Guth [1988] explains the experimental results of Roth and Murnighan [1982] in this way. See also Foddy [1989] for a closely related explanation of that data.

3. This point of view is very clearly expressed, for example, in Harrison [1990] and Harrison and McCabe [1991].

4. However, we should emphasize that our investigation does not address the cognitive processes by which subjects arrive at tradeoffs between considerations of fairness and of strategy.

compare their payoffs, and that notions of fairness would come to the fore if the experiment were repeated under conditions like those of the ultimatum experiments.

To distinguish between these "strategic" and "information" hypotheses, the first part of the present paper reports an experimental comparison between best-shot and ultimatum games conducted under comparable information conditions (and between best-shot games conducted under different information conditions).

When the results of these comparisons were circulated for comments [Prasnikar and Roth, 1989], a new hypothesis about the difference between best-shot and ultimatum games was raised by Guth [personal communication] and Guth and Tietz [1990], who noted that the set of feasible agreement payoffs in best-shot games is not convex. In particular, Guth and Tietz observed that there was no Pareto optimal agreement that gave both players equal payoffs, and they suggested that considerations of fairness might not arise in such games. To address this issue, we have added a third comparison game, a multiplayer market game with a convex set of agreement payoffs, all of which are Pareto optimal, whose equilibrium predicts unequal payoffs comparable to the equilibrium predictions for the other two games.

In this connection, a comment on method seems appropriate. Both in economics and in other scientific disciplines, it is perhaps more traditional than is generally acknowledged for investigators with very different hypotheses to largely ignore each other, or to address each other only tangentially. This is partly because different hypotheses suggest different directions for further work. And this is as true for experiments as for other kinds of research: the experimental comparisons that seem most appropriate for refining a hypothesis and testing it against its near alternatives may be very different for different hypotheses. The consequence is that different groups of investigators concerned with related phenomena may each discount the importance of what the other group regards as the most important part of the evidence. To some extent this has been the case in the experimental study of sequential bargaining: investigators who emphasize social norms have concentrated primarily on single-period games, while investigators who emphasize strategic considerations have primarily concentrated on multiperiod games.[5] The present paper is an

5. Guth, Ockenfels, and Tietz [1990] note [p. 6] that "In spite of the apparent popularity of ultimatum bargaining few experiments have tried to explore the behavior in the basic game situation. . . . To our knowledge this has been done only

attempt to address this situation by comparing three single-period games that are interpretable in terms of the hypotheses in the two parallel literatures on this subject. We hope that this kind of cross fertilization may help suggest refinements of both kinds of hypotheses.

This paper is organized as follows. Section II briefly describes ultimatum and best-shot games, and the results obtained for these games by previous experimenters. Section III describes our new experimental comparisons involving these games, and Sections IV and V analyze and interpret the results. Section VI discusses the hypothesis raised by Guth and Tietz to account for these results, and presents the further experimental comparison designed to address this hypothesis. Section VII concludes.

II. Prior Experimental Results

A. Ultimatum Games

An ultimatum bargaining game is a two-person game played as follows. There is some quantity Q of money to be divided, and player 1 makes a proposal of the form (x_1, x_2), where $x_2 = Q - x_1$. Player 2 then has an opportunity either to accept or reject this proposal: if player 2 accepts, then player 1 receives x_1, and player 2 receives $x_2 = Q - x_1$; if player 2 rejects, then each player receives zero.

Under the assumption that each player's own monetary payoff is a measure of his utility, the perfect equilibrium prediction for this game is that player 1 will demand all (or, in the case of discrete payoffs, almost all) of the profit, and that player 2 will accept. That is, the division of Q that results from perfect equilibrium gives player 1 a payoff of Q (or $Q - \epsilon$ if there is some smallest divisible quantity ϵ of money), and player 2 a payoff of zero (or ϵ).

Observed experimental results have been quite different, with player 1's, predominantly offering player 2's much larger shares (typically in the neighborhood of 40 percent of Q: See Guth and Teitz [1990] for a survey). Similar results have been observed in two-period or multiperiod extensions of the game, in which a rejection by player 2 does not immediately end the game, but leads

by Guth, Schmittberger and Schwarz [1982], Guth and Tietz [1985, 1986], Kravitz and Gunto [1988] and Prasnikar and Roth [1989]. In all other studies the ultimatum bargaining decisions were either embedded in a larger [multiperiod] game context . . . or subjects assumed the positions of both players in two different games . . ."

instead to a period in which player 2 may now propose a division of some smaller quantity δQ, which player 1 may accept or reject. In the two-period game, again under the assumption that each player's own monetary payoff is a measure of his utility, the perfect equilibrium prediction is that player 1 will propose $([1 - \delta]Q, \delta Q)$ and player 2 will accept (since in the next period the perfect equilibrium would be for player 2 to propose $(0, \delta Q)$ and for player 1 to accept). Ochs and Roth [1989] observed that it was not uncommon, when player 1 proposed that he receive "too large" a share x_1 of Q (even though $x_1 < [1 - \delta]Q$), that player 2 rejected this proposal and responded with a "disadvantageous counter-proposal" that even if accepted would give him less than the amount $x_2 = Q - x_1$ that player 1 had offered him. They also reanalyzed the data from a number of earlier experiments [Guth, Schmittberger, and Schwarz, 1982; Binmore, Shaked, and Sutton, 1985; Guth and Tietz, 1988; Neelin, Sonnenschein, and Spiegel, 1988] and observed that this phenomenon had occurred similarly in previous experiments. In particular, subjects in the role of player 2 seemed prepared to reject markedly unequal payoff distributions even if they could not expect to obtain a larger payoff in the second or subsequent periods.

Ochs and Roth concluded that subjects had preferences not only over their own monetary payoffs, but also over distributions of payoffs between them and the other bargainer, and sketched a class of models in which these preferences are taken into account in players' strategic decisions. (For a set of experiments that investigate such a model in some detail, see Bolton [1991], and see Roth [1992] for a survey.) Guth and Tietz [1990, p. 440], however, write that they "strictly reject" explanations involving tradeoffs between preferences and strategic considerations. Rather, they write, "all our experiences from ultimatum bargaining experiments indicate that subjects do not 'maximize' but are guided by sometimes conflicting behavioral norms."

B. The Sequential "Best-Shot" Games of Harrison and Hirshleifer

These games also involved two players. (Harrison and Hirshleifer [1989] observed six subjects in eighteen one-period encounters: each subject played six games against an anonymous opponent who changed from period to period.) The rules were that player 1 states a quantity q_1, after which player 2, informed of q_1, states a quantity q_2. An amount of public good equal to the *maximum* of q_1 and q_2 (the "best-shot") results, and each player i receives the payoff corresponding to that quantity of public good minus \$0.82 times q_i (see Table I). Harrison and Hirshleifer [p. 207] state: "No subject was informed of the payoffs of any other subject in our experiments, and in particular the fact that all valuation schedules were the same was not revealed. Our theoretical analysis, in contrast, presumes that the payoffs are common public knowledge." Harrison and Hirshleifer go on to argue that this "informational discrepancy" made their experiments a severe test of the perfect equilibrium predictions, which are that player 1 will choose $q_1 = 0$ and player 2 will choose $q_2 = 4$, giving player 1 a

TABLE I

REDEMPTION VALUES AND EXPENDITURE VALUES FOR THE BEST-SHOT FULL AND PARTIAL INFORMATION GAMES

	Redemption values		Expenditure values	
Project level (units)	Redemption value of specific units	Total redemption value of all units	Number of units you provide	Cost to you of the number of units you provide
0	\$0.00	\$ 0.00	0	\$ 0.00
1	1.00	1.00	1	0.82
2	0.95	1.95	2	1.64
3	0.90	2.85	3	2.46
4	0.85	3.70	4	3.28
5	0.80	4.50	5	4.10
6	0.75	5.25	6	4.92
7	0.70	5.95	7	5.74
8	0.65	6.60	8	6.56
9	0.60	7.20	9	7.38
10	0.55	7.75	10	8.20
11	0.50	8.25	11	9.02
12	0.45	8.70	12	9.84
13	0.40	9.10	13	10.66
14	0.35	9.45	14	11.48
15	0.30	9.75	15	12.30
16	0.25	10.00	16	13.12
17	0.20	10.25	17	13.94
18	0.15	10.35	18	14.76
19	0.10	10.45	19	15.58
20	0.05	10.50	20	16.40
21	0.00	10.50	21	21.22

profit of $3.70 and player 2 a $0.42 profit.[6] That is, they interpret their experimental evidence, which is strikingly close to the perfect equilibrium predictions, as evidence in favor of the combined hypothesis "that subjects correctly conjectured that their payoffs were identical," and that they would play perfect equilibrium strategies in the game which resulted.

Note also, however, that players' lack of information about each other's payoffs may have disabled whatever countervailing force in favor of more equal distributions of payoffs was at work in the bargaining games reported above. That is, perhaps the reason subjects in the role of player 2 were willing to accept a payoff of $0.42 was because they were unaware (or unsure) that player 1 was receiving $3.70, in contrast to the case of ultimatum bargaining games in which such extreme payoff disparities proved to be unacceptable.[7] (Guth's [1988] theory of hierarchical social norms, accessed according to the information available, would presumably account for the results in this way.) This could potentially explain why such a relatively extreme distribution of payoffs was observed in the data, but virtually never in the data from ultimatum games for comparable amounts of money.[8]

The first comparison in the new experiment reported below was designed in part to distinguish between these hypotheses, by examining sequential best-shot games in which the subjects were explicitly told that their payoffs were identical, and comparing these with games in which they were not. (The results of Roth and Murnighan [1982] show, for a different bargaining environment,

6. To see that this is the unique perfect equilibrium, observe from Table I that if player 1 provides $q_1 = 0$, then player 2's unique best response is to provide $q_2 = 4$, since the first four units of public good all have a higher marginal value than the cost to player 2 of providing each unit, while the fifth unit of public good has a lower marginal value. And if player 1 provides a quantity $q_1 \geq 1$, then player 2's unique best response is to provide $q_2 = 0$, which gives player 1 a strictly lower payoff than if he provides 0 and player 2 provides 4.

7. Guth and Tietz [1988, p. 113] write that "Our hypothesis is that the consistency of experimental observations and game theoretic predictions observed by Binmore et al. . . . is solely due to the moderate relation of equilibrium payoffs which makes the game theoretic solution socially more acceptable." They note that Binmore et al. [1985] examined two-period bargaining games whose equilibrium prediction was for payoffs in the ratio 3:1. In their own experiment Guth and Tietz employed equilibrium payoff ratios of 9:1. So the equilibrium payoff ratio in these best-shot games is virtually identical to those in the bargaining games discussed by Guth and Tietz, since $3.70/$0.42 = 8.8.

8. Harrison and Hirshleifer report in a footnote [1989, p. 208, fn. 7] that they ran some full information games with similar but somewhat different results. In a personal communication in reply to an earlier draft of this paper, Harrison informed us that there were procedural differences between the games (including the fact that the games reported by Harrison and Hirshleifer were run by hand, while the games referred to in the footnote were run by computer) that precluded comparing them.

that such changes in information may have important effects on the observed outcomes.)

III. Experimental Comparison of Best-Shot and Ultimatum Games

The subject pool for the experiments reported here consisted of undergraduate students at the University of Pittsburgh. No special skill or experience was required for participation. Subjects were told they would be paid $5 for showing up on time, and that they would have an opportunity to earn additional money in the experiment.

A. The Sequential "Best-Shot" Game

The experiment varied the information players had about each other's payoffs, by implementing two information conditions. Subjects in the full information condition were explicitly told that each of them had the same payoffs and in the instructions this was stated as: . . . "Attached to the instructions you will find a sheet called the *Redemption Value Sheet* which is *identical* for all individuals." In the partial information condition, following Harrison and Hirshleifer [1989] the information about the payoffs was presented as follows: ". . . you will find a sheet called the *Redemption Value Sheet.* It describes the *value to you* of the decisions made in each round. *You are not to reveal this information to anyone.* It is your own private information."

Each subject participated in only one of the information conditions in ten consecutive encounters, facing different individuals. In the partial information condition there were twenty participants. In the full information condition there were sixteen participants.[9] Participants were assembled in a room and randomly assigned identification numbers that determined whether they would be in the position of the first or second player. Accordingly, they were seated on the left or the right side of the room. The instructions were distributed and read aloud. The players were also required to keep records of the quantities provided by themselves and by the other agent, maximum quantity selected, and earnings. In the full information condition the players also recorded the earnings of the other player. After the instructions were read, a

9. The smaller number of players was due to "no shows" among the subjects.

practice game was played. In the subsequent rounds, each participant played with each participant on the other side of the room, without knowing with whom he was playing in any given round. Subjects knew they would be playing with a different person from round to round. In the full information condition subjects were told that for the last two rounds they would be playing participants with whom they had played in earlier rounds, because only sixteen players participated. (The identification numbers of the subjects were changed after the seventh round so that they would not be able to identify whom they encountered twice.) Subjects were told that, at the conclusion of the experiment, they would be paid in cash the sum of their earnings in four out of the ten rounds, which would be chosen randomly.

B. Ultimatum Game

In order to control for possible effects attributable to the subject pool, the comparison set of ultimatum games we shall discuss were run contemporaneously with the best-shot games, at the University of Pittsburgh, using the same general procedures.[10] Sixteen subjects participated. Subjects had \$10 to divide,[11] so player 1's proposal was a division of the form (\$$x_1$, \$$x_2$) with $x_2 =$ \$$10 - x_1$.

IV. Principal Results for Best-Shot and Ultimatum Games

A. Observations Related to the Equilibrium Predictions

Table II reports the mean offers x_2 ($x_2 = Q - x_1$) in the ultimatum game, as well as the mean quantities q_1 provided in the sequential best-shot games under full and partial information. Recall that the perfect equilibrium prediction is that all these

10. The ultimatum games were part of an ongoing experimental investigation (see Roth, Prasnikar, Okuno-Fujiwara, and Zamir [1991]) for which some additional comparisons were required. For these comparisons, player 1's were also asked to record what they thought was the likelihood that their proposed division would be accepted, and player 2's were asked to record their estimate of what the first player's proposal would be. Proposed divisions had to be in units no smaller than \$0.05. Subjects were told that, at the conclusion of the experiment, one of the ten rounds would be chosen at random and they would be paid the result of that round. Subsequently, further data have been gathered on these games from the same subject pool, and the data reported here are representative of the larger data set.

11. In all of these games, the player 1's were described as buyers, player 2's as sellers, and the proposed division was in the form of a price proposal, with corresponding payoffs (p, 10-p).

TABLE II
MEAN OFFERS BY PERIODS (VALUES IN PARENTHESES ARE STANDARD ERRORS)

Periods	Ultimatum game mean offers x_2 (perfect equilibrium prediction $x_2 = 0$)	Best-shot full information game (perfect equilibrium prediction $q_1 = 0$)	Best-shot partial information game (perfect equilibrium prediction $q_1 = 0$)
1	4.188	1.625	2.700
	(0.329)	(0.610)	(0.617)
2	3.825	0.875	2.900
	(0.530)	(0.482)	(0.994)
3	3.725	1.125	3.000
	(0.480)	(0.597)	(0.848)
4	3.581	0.125	2.100
	(0.438)	(0.116)	(0.793)
5	4.231	0.125	2.700
	(0.276)	(0.116)	(0.906)
6	4.418	0.125	1.250
	(0.234)	(0.116)	(0.605)
7	4.294	0.000	1.100
	(0.166)	(0.000)	(0.537)
8	4.531	0.000	0.800
	(0.155)	(0.000)	(0.505)
9	4.325	0.000	0.950
	(0.232)	(0.000)	(0.567)
10	4.531	0.000	0.700
	(0.155)	(0.000)	(0.401)
Durbin-Watson**	2.27	2.01	1.945
Mean	4.165	0.401	1.820
	(0.110)	(0.118)	(0.240)
N	80	80	100

**Durbin-Watson Test for the transformed residuals.

quantities will be zero. The observed means are reported round by round for each game.[12]

In the sequential best-shot game under full information, the observed means converge precisely to the equilibrium prediction. For the best-shot games under partial information, although the observed means move in the direction of the equilibrium prediction, we reject the hypothesis that the mean offers are equal for the

12. In all three experiments each subject played ten consecutive games. Potential learning effects (diminishing variance by periods) and autocorrelation raise problems for analyzing the data. Econometric methods and tests were used to handle the problem of heteroskedasticity and autocorrelation over periods. Let $y_{it} = \mu_t + \epsilon_{it}$, where i indexes individuals and t indexes periods. Consider the following

full information and partial information game for each period.[13] However, the observed means in both best-shot games are clearly much closer to zero than are the observed means in the ultimatum games, which are quite similar to the observations for ultimatum games that have already been reported in the literature.

B. Behavior Off the Equilibrium Path

Behavior *off* the equilibrium path can be assessed by considering how player 2's react when player 1's offer $q_1 > 0$ in the best-shot games or when player 1's offer $x_2 > 0$ in the ultimatum games. The prediction of subgame perfect equilibrium is in all cases that player 1 will maximize his payoff by making the equilibrium offer; i.e., at perfect equilibrium the predicted response of player 2 is such that a positive offer will yield player 1 a lower payoff than an offer of zero. However, as the graphs in Figure I make clear, the best-shot games exhibit strikingly different behavior in this regard than the ultimatum games.[14] In the best-shot games, under both information conditions, the average payoff of player 1's who contributed the equilibrium quantity $q_1 = 0$ is greater than that of player 1's who contributed positive quantities. However, in the ultimatum game, the average payoff to a player 1 who offers player 2 an amount x_2 rises to a maximum for x_2 between four and five. So in the ultimatum games a player 1 does better as he deviates further from equilibrium, but not in the best-shot games.

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error structure:

$$(*)\epsilon_{it} = \rho\epsilon_{it-1} + u_{it}, \qquad E(u_{it}^2) = \sigma_t^2,$$

and $E(\epsilon_{it}, \epsilon'_{jt}) = 0$ if $i \neq j$. To test whether σ_t^2 is constant across t, we use the Breusch-Pagan (score) test. The test statistics are 87.59 for the full information game, 17.95 for the partial information game, and 27.48 for the ultimatum game. Since the critical value is χ^2 (0.95;9) = 16.90, this indicates the presence of heteroskedasticity. We corrected for the presence of heteroskedasticity using White's [1980] consistent estimator of Σ. To test for autocorrelation, we estimate ρ in (*) while imposing the constraint $\sigma_t^2 = \sigma^2$. The estimates of ρ are 0.247 (standard error = 0.109) for the full information game, 0.644 (standard error = 0.076) for the partial information game, and 0.694 (standard error = 0.081) for the ultimatum game. Thus, we also find evidence of positive autocorrelation. A test of the joint null hypothesis of no heteroskedasticity and no autocorrelation produced a test statistic of 21.43 which is greater than the critical χ^2 (0.95;10) = 18.30). All test statistics in the remainder of the paper are based on the general error structure (*).

13. We tested the hypothesis that the mean offer for the full information game (μ_{ft}) equaled the mean offer in the partial information game (μ_{pt}) for each t. The (Wald) test statistic is 19.6, which is larger than the critical value χ^2 (0.95;10) = 18.3, and thus we reject the null hypothesis $\mu_{ft} = \mu_{pt}, t = 1,2,\ldots,T$.

14. In the graph of average earnings in the ultimatum game, offers x_2 are aggregated by their integer part; i.e., offers to player 2 of 4 and 4.5 are both listed as $x_2 = 4$. For the unaggregated data see Figure IV.

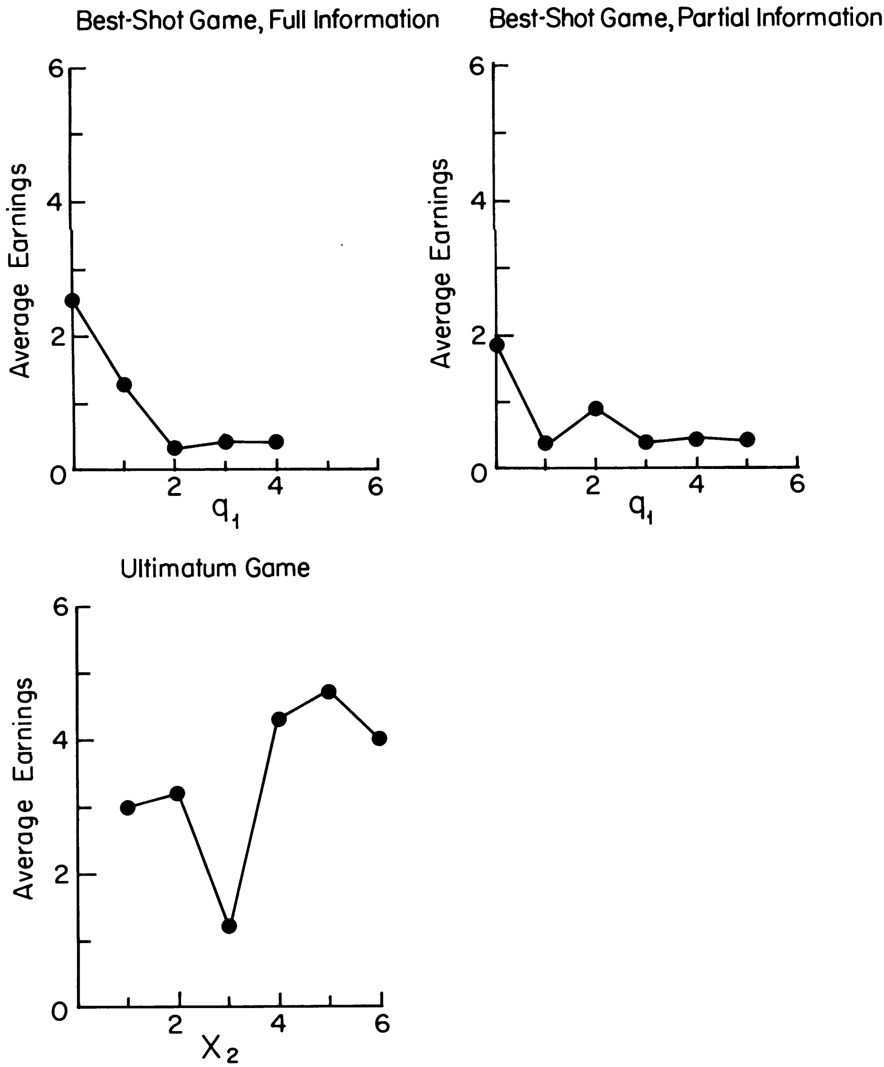

FIGURE I
Average Earnings of Player 1

C. Learning Behavior

The fact that no player 1 deals with the same player 2 from one period to the next, and that all play is anonymous, preserves the single-period strategic character of the games in this experiment. However, the fact that each subject plays ten consecutive games

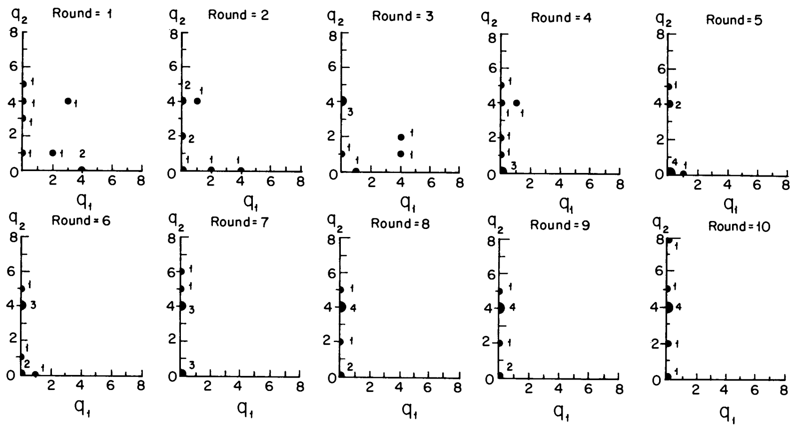

FIGURE II
Best-Shot Game, Full Information: Distribution of Outcomes

means that there is an opportunity for subjects to learn about the game, and about the behavior of other players in the subject pool.

One indicator of this is that the variance of the data in each round (see Table II) diminishes from round 1 to round 10 in all of the games (and goes to zero in the best-shot full information condition). In the best shot games, half the player 1's in the full information condition (see Figure II)[15] and nine out of ten of the player 1's in the partial information condition (see Figure III) began by offering positive quantities, but in the face of consistent lack of a positive reply by the player 2's the number of player 1's offering positive quantities steadily diminished. In contrast, in the ultimatum game (Figure IV) first player offers were closest to the equilibrium prediction in the first four rounds, but in the face of steady rejections, the lowest offer x_2 steadily climbed. We can also look for an effect of learning by testing if the mean offers are the same in all the periods.[16] The tests show that only for the

15. Figures II and III are read as follows. Each outcome is represented by a circle centered on that outcome, with the number of occurences of a particular outcome reflected by the size of the circle, and the number next to it. For example, Figure II shows that in round 1 of the full information condition the outcome $(q_1, q_2) = (4,0)$ was observed twice, while the outcomes (2,1), (0,1), (0,3), (0,4), (3,4), and (0,5) were each observed once.

16. The test statistics Y and critical F values are as follows: (1) time specific fixed effect versus no time effect (i.e., the mean was restricted to be equal in all periods) for the full information game ($Y = 3.038$, $F(0.95;9,70) = 2.03$), (2) time specific fixed effect versus no time effect for the partial information game ($Y = 2.32$, $F(0.95;9;90) = 2.08$), (3) time specific fixed effect versus no time effect for the ultimatum game ($Y = 1.029$, $F(0.95;9,70) = 2.03$).

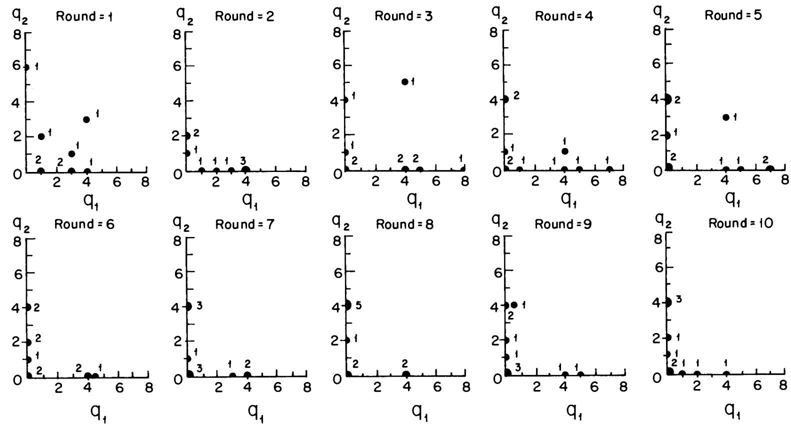

FIGURE III
Best-Shot Game, Partial Information: Distribution of Outcomes
In the first round there was one additional outcome of $(q_1, q_2) = (7, 21)$. In the second round there was one additional outcome of $(q_1, q_2) = (11, 0)$.

ultimatum game is the hypothesis of equal mean offers by periods not rejected.

Figures II and III give a clear picture of the learning that took place in the best-shot games, and how it differed in the two information conditions. Looking first at the full information

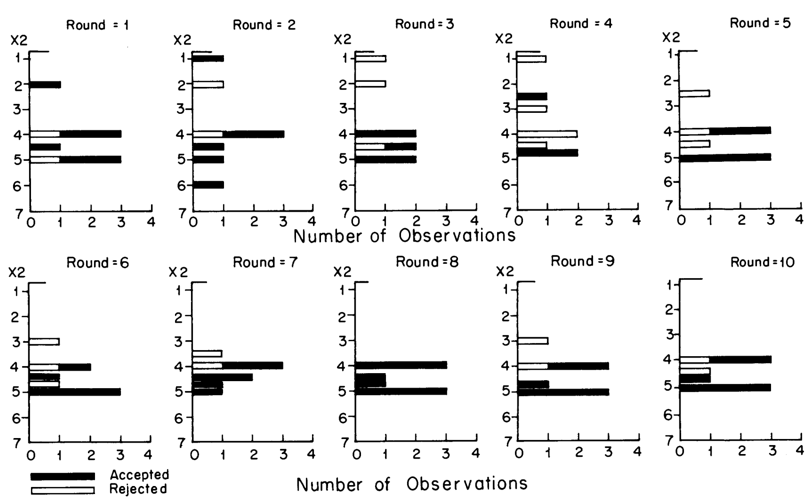

FIGURE IV
Ultimatum Game: Distribution of Outcomes

condition, Figure II shows that only in the first four rounds are there outcomes at which both player 1 and 2 contribute positive quantities. From round 5 on no more than one player in each pair contributes a positive quantity, and from round 7 on no player 1 contributed a positive quantity, while the number of player 2's contributing a positive quantity rose from five out of eight in round 7 to seven out of eight in round 10, with the modal response being the equilibrium quantity. In the partial-information condition Figure III shows that while it did not take much longer for the players to learn that only one of them should provide a positive quantity, even by round 10 there were still pairs in which it was player 1 who was providing the public good. Thus, the evidence suggests that in the full information condition player 1's were better able to anticipate the reaction of player 2's.

V. Interpretation of the Results

One of the hypotheses with which we began this investigation was that the convergence to perfect equilibrium quantities observed by Harrison and Hirshleifer [1989], in stark contrast to experimental results for ultimatum bargaining games, might be due to the fact that participants in their experiment were not informed of one another's payoffs. This has not proved to be the case: in both of our information conditions for best-shot games, the observed quantities provided approach the equilibrium quantity by the tenth round;[17] in contrast to the results for ultimatum games, in which the results remain far from the equilibrium predictions.

That these two different classes of games yield very different results in spite of having very similar perfect equilibrium predictions thus seems to be a reliable result. Our evidence suggests that the explanation for this difference lies in the off the equilibrium path behavior (recall Figure I).[18] It is illuminating in this connec-

17. Of course we did observe differences between the two information conditions. And although Harrison and Hirshliefer's [1989] experimental instructions implemented a version of our partial-information condition, their results more closely resemble those of our full-information condition. These observations suggest that, here as in Roth and Murnighan [1982], information is a volatile experimental variable that requires extremely careful control. This is particularly so since there are many opportunities for experiments to reveal to subjects information about which nothing is said in the formal instructions, for example, through repeated play, or when questions are answered in the course of presenting the instructions.

18. Alternative explanations offered in the earlier literature concerned with bargaining games seem to have little force here. Since the equilibrium payoffs in these best-shot games are as extreme as those in the games examined by Guth and Tietz [1988] (recall our footnote 7), the observation of equilibrium play in these games but not in those (and not in the ultimatum games) cannot be attributed to

TABLE III
THE PAYOFF MATRIX FOR THE SEQUENTIAL "BEST-SHOT" GAME

		Player 2 provides					
		0	1	2	3	4	5
	0	0, 0	1.00, 0.14	1.95, 0.31	2.85, 0.39	3.70, 0.42	4.50, 0.40
	1	0.18, 1.00	0.18, 0.18	1.13, 0.31	2.03, 0.39	2.88, 0.42	3.68, 0.40
Player 1	2	0.31, 1.95	0.31, 1.13	0.31, 0.31	1.21, 0.39	2.06, 0.42	2.86, 0.40
provides	3	0.39, 2.85	0.39, 2.03	0.39, 1.21	0.39, 0.39	1.24, 0.42	2.04, 0.40
	4	0.42, 3.70	0.42, 2.88	0.42, 2.06	0.42, 1.24	0.42, 0.42	1.22, 0.40
	5	0.40, 4.50	0.40, 3.68	0.40, 2.86	0.40, 2.04	0.40, 1.22	0.40, 0.40

tion to examine the payoffs to the players for each pair of actions for the two kinds of games. Table III shows the payoffs to the players in the best-shot games for each pair (q_1, q_2). (Note that this is *not* a strategic form representation of the game: since player 2 moves second, his strategies are not simple quantities q_2, but rather functions from q_1 to q_2). Once player 1 departs from equilibrium and offers a positive q_1, player 2's best response is always to provide $q_2 = 0$. This conforms with the observation in Figure I that player 1's got little positive reinforcement for departures from equilibrium. This contrasts with the incentives to player 2's in the ultimatum game, who have more incentive to accept an offer the farther it is from equilibrium. And this in turn conforms with the behavior observed in the ultimatum game (compare Figures I and IV). The data thus clearly support the "strategic hypothesis" as opposed to the "information hypothesis" as outlined in our introduction, for these games.

VI. AN ALTERNATIVE HYPOTHESIS

Guth and Tietz [1990] suggest that best-shot games are not appropriate comparisons to ultimatum games for the purposes of discerning how strategic considerations may interact with perceptions of fairness. In particular, they propose that considerations of fairness may not arise in best-shot games because the set of feasible agreements is not convex, so that there is no way for the players to

differences in the distributions of income. Conversely, the persistence of much more equal payoff distributions in the ultimatum games cannot easily be attributed to lack of understanding or experience, since the ultimatum game players had no less experience than the best-shot players, and by virtually any measure it is the best-shot game that is more complex and difficult to understand.

share the maximum payoff equally. Specifically, they say the following: "Equal positive contributions in best shot games are obviously inefficient since one of the two contributions is completely useless. If sharing the burden of providing the public good is impossible, fairness considerations cannot be applied. Furthermore, the very obvious aspect of efficiency requires extreme payoff distributions" [p. 428].

These comments refine Guth and Tietz's [1988] hypothesis concerning the role played by extreme payoff distributions (recall footnote 7), by adding considerations of convexity and efficiency. In doing so, they raise a clear counterhypothesis to the interpretation we have given above to the observed differences between best-shot and ultimatum games. According to our interpretation, the different off-the-equilibrium-path properties of the two games is responsible for the different observed behavior, despite the comparably unequal payoff distribution at equilibrium. The contrary hypothesis now suggested by the remarks of Guth and Tietz [1990] is that the different observed behavior in the two games is due to the fact that players are concerned with fairness only in the ultimatum games, and that no comparable considerations arise in the best-shot games in which equality is incompatible with efficiency.

To test this hypothesis, we next consider a game with extreme equilibrium payoffs, but with a convex set of efficient agreements. While this game differs from the games we have been considering in a number of respects, most notably in the number of players, it allows us to compare the nonstrategic and strategic hypotheses that have been advanced to explain their behavior.

A. Sequential Market Games with Many Buyers and One Seller

Each sequential market consisted of one seller and nine buyers. As in the ultimatum games, each buyer offered a price, which if accepted determined the division of \$10 between the successful buyer and the seller. (If the seller accepts an offer p from buyer 1, then that buyer earns \$10 $- p$, the seller earns \$$p$, and all other buyers earn \$0. If the seller rejects all offers, then all players in the market receive \$0.) Twenty subjects participated, each playing ten rounds. In each round, two markets, A and B, operated simultaneously, and buyers were switched between the markets from round to round, so that the composition of the markets was not the same in any two rounds.[19] In each round every buyer submitted a price, and the maximum price in each market was reported to the seller in that market, who could accept or reject it. The transactions were then made public (by being recorded on a blackboard). Successful buyers were identified only by anonymous identification numbers. If more than one buyer offered the maximum price (and it was accepted), then one of those buyers would be chosen at random to complete the transaction. As in the ultimatum games, \$0.05 was the smallest unit in which prices could be stated.[20]

The stage game just described can be thought of as an auction for an indivisible good worth \$10 to any buyer. Any subgame perfect equilibrium gives (virtually) all the wealth to the seller. Specifically, any distribution of prices can occur at a perfect equilibrium if two or more buyers bid \$10, and (since bids must be discrete) another perfect equilibrium has all buyers bidding \$9.95. Thus, the equilibrium distribution of income has all buyers earning either zero or a one-ninth probability of earning \$0.05, while the seller earns either \$10.00 or \$9.95.

However, in this game all transactions, not merely equilibrium transactions, are efficient. There are two kinds of equal-payoff outcomes: if all buyers offer a price of \$1, then every player has an expected payoff of \$1, and if all buyers offer a price of \$5, then the successful buyer will have the same payoff as the seller (and all buyers will have the same expected payoff of \$0.56).

Thus, this game has equilibrium payoff distributions that are as extreme as those of the ultimatum or best-shot games, but (like the ultimatum game and unlike the best-shot game) it has efficient equal-payoff outcomes. It therefore presents an opportunity to test the conjecture that the observed outcomes of the best-shot games were intimately related to the fact that equal payoffs in that game can only be achieved inefficiently.

19. In each round each buyer knew the market in which he was participating, but not which other buyers were in the same market. This was intended to make each round resemble as closely as possible a one-period game, by eliminating the possibility that buyers could coordinate their efforts (e.g., by taking turns at being the high bidder). See Ochs [1990] for a fuller discussion of this kind of manipulation.

20. These market games were conducted so as to be as comparable as possible to the ultimatum games, so as to allow further comparisons as part of a larger study [Roth, Prasnikar, Okuno-Fujiwara, and Zamir, 1991]. As in the ultimatum game, subjects remained either buyers or sellers for all ten rounds, and one round was chosen at random to determine the payoffs. As in the case of the ultimatum games, the data reported here are representative of the larger data set that has subsequently been collected.

TABLE IV

THE HIGHEST AND SECOND HIGHEST PRICES IN EACH OF THE MARKETS AND THE BASIC DESCRIPTIVE STATISTICS

Period	Market	The highest price $p*	The second highest price $p*	Mean (SD)	Mode	Median	N**
1	A	8.90 (1)	8.25 (1)	6.48 (2.52)	8.05	8.05	9
	B	9.90 (1)	8.95 (1)	6.76 (1.84)	5.00	6.50	9
2	A	9.60 (1)	9.00 (1)	6.57 (3.07)	5.00	8.05	9
	B	9.90 (1)	9.00 (2)	6.69 (3.26)	x	8.00	9
3	A	9.85 (1)	9.65 (1)	7.24 (3.24)	x	9.00	9
	B	10.00 (1)	9.95 (1)	8.08 (2.31)	x	9.00	9
4	A	10.00 (2)	9.95 (2)	7.32 (4.00)	x	9.90	9
	B	9.95 (1)	9.90 (1)	7.31 (2.67)	9.00	9.00	9
5	A	10.00 (2)	9.95 (2)	9.14 (1.61)	x	9.90	9
	B	10.00 (2)	9.95 (2)	7.93 (2.76)	x	8.50	9
6	A	10.00 (3)	9.95 (1)	7.21 (3.69)	10.00	9.00	9
	B	10.00 (1)	9.95 (4)	7.81 (3.32)	9.95	9.95	9
7	A	10.00 (1)	9.95 (2)	6.43 (3.28)	x	7.00	9
	B	10.00 (1)	9.60 (1)	5.23 (3.07)	5.00	5.00	9
8	A	10.00 (2)	9.85 (1)	5.76 (3.74)	x	5.00	9
	B	10.00 (2)	9.85 (1)	5.72 (4.31)	x	7.00	9
9	A	10.00 (1)	9.95 (1)	4.73 (4.11)	x	5.00	9
	B	10.00 (1)	9.95 (1)	5.98 (3.72)	x	5.00	9
10	A	10.00 (2)	9.95 (1)	6.22 (4.23)	x	9.00	9
	B	10.00 (2)	9.95 (1)	6.47 (3.32)	5.00	5.00	9

*The number in parentheses is the number of buyers who bid that price.
**N represents the number of buyers in each of the markets.
x An x in the mode column means that there were fewer than three observations at any one price.

The results are summarized in Table IV, which shows the highest and second highest prices bid in each market in each round, and the number of bids received at each of those prices, together with statistics on the remaining bids. (Neither seller rejected the maximum bid in any round.) By the fifth round prices had converged to equilibrium, and all subsequent transactions were at the equilibrium price of $10.[21] That is, contrary to the above conjecture, we see very unequal payoffs emerging even though equal payoffs are also efficient.

Table IV also makes clear that (except in round 7 in market B) from round 5 on no buyer could have increased his payoff by more than $0.05 by changing his bid. In particular, the high bidders in these rounds (who always received zero) were always competing with either another bidder who made the same bid, or one who made a bid that was only $0.05 less. Thus, in this game, as in the best-shot game and in contrast to the ultimatum game (recall Figure I), the observed pattern of play is such that agents could not increase their payoff by deviating from the equilibrium prediction. This lends further support to the strategic hypothesis proposed to explain the difference in behavior observed between those two games.

It is noteworthy that the high bids were not submitted by a small proportion of the buyers (in which case we might have supposed that the high bidders were unrepresentative of the buyer population). *Half* of the buyers (nine out of eighteen) submitted at least one bid of $10. At the same time (and also consistent with the equilibrium prediction) Table IV also shows that there was considerable diversity. The equal-payoff bid of $5 was the modal bid in four (out of twenty) market rounds, with two of these coming in rounds 7 and 10, when the buyers who made these proposals had abundant evidence that these would not be the winning bids, and that all bids would yield zero or negligible payoffs. So these bids may be (cautiously) interpreted as evidence that the ideas about fairness captured by the equal payoff outcomes in this game were present in this subject population.[22] Nevertheless, as in the best-

21. In subsequent experiments with this game, the transaction price has sometimes settled down at $9.95 (see Roth, Prasnikar, Okuno-Fujiwara, and Zamir [1991]).

22. The idea here is that, once the equilibrium becomes established, so that bidders observe that no bid they make will earn them positive profits, then some bidders may choose their bids on other criteria, and the observation of $5 bids suggests that these have some appeal.

shot games, the dynamics of the game forced the outcome toward equilibrium.[23]

Note that we are not claiming that the dynamics that led to equilibrium in the later rounds of this game are necessarily due to simple income maximization, although it would be surprising if this did not play some role. To be clear about what we mean, it may be useful to speculate a little, beyond the evidence, about buyers' motivations. Consider a hypothetical buyer whose preference for equality is such that his very first choice outcome would be to have all buyers submit identical bids of $5 (or $1), and who bids accordingly in the first two rounds. When he sees how high the actual transaction price is, he becomes annoyed with the other buyers, and (with the same motivation that would have caused him to express his displeasure by rejecting too small an offer if he were a seller in the ultimatum game) he decides to become the high bidder in round 3, in order to deprive other buyers of the benefits of what he sees as their unreasonable behavior. The point in considering such a hypothetical buyer is to observe that in *this* game his nonmonetary preferences cause him to behave in a manner indistinguishable from an income maximizer, while in the ultimatum game his preferences lead away from the equilibrium predicted for income maximizers. The difference lies not in the preferences, or in the "social norms" elicited by the game that these preferences may reflect, but in how such preferences interact in the different games, and in the outcome that emerges.[24]

VII. Concluding Remarks

In this paper we have reported experimental observations, under comparable conditions, of three different kinds of games, all of which have very unequal payoff distributions at equilibrium, when players are assumed to be simple income maximizers. In

23. A number of people have expressed surprise that subjects would make an (equilibrium) bid that guaranteed them zero profit, but have found it less surprising that in subsequent replications of this market the maximum price in many rounds is $9.95, which gives a profit of $0.05 to the winning bidder. It seems to us, however, that both bids are equally surprising or unsurprising, since for all practical purposes the difference in expected payoff between the two bids is negligible. And the convergence to equilibrium in this game is robust: to date we have seen it in each of the replications we have conducted in four countries (see Roth, Prasnikar, Okuno-Fujiwara, and Zamir [1991]).

24. And to the extent that players' preferences, including their preferences for "fairness," interact in different ways in different games, it seems appropriate to model these preferences separately from the game itself, for example in the preferences of the players, as suggested by Ochs and Roth [1989].

ultimatum games the observed payoff distributions are much more equal than the (income-maximizing) equilibrium distributions, but in the best-shot and market games the (income-maximizing) equilibrium payoff distributions were observed with great clarity.

Taken together, these results suggest that although equilibrium predictions may need to be modified to take into account nonmonetary aspects of players' preferences (e.g., in the ultimatum games), nevertheless, even when equilibrium yields very unequal payoffs, strategic considerations are not *displaced* by considerations of equity. On the contrary, the best-shot and market games show that whether equilibria will be observed depends on the off-the-equilibrium-path behavior, which responds to the off-the-equilibrium-path incentives.[25] And we could almost take this to be a definition of strategic thinking, in which the predicted behavior is maximizing behavior that correctly takes into account agents' responses to alternative courses of action.

At the same time it should be emphasized again that the ultimatum games show that ideas about fairness need not be displaced by considerations of strategy, either. The preferences that player 2's exhibit for relatively equal payoff distributions are if anything probably reinforced by experience with the game (see Figure IV), since low offers became rare. In contrast, Figure II shows that in the best-shot game, player 2's also displayed considerable resistance to unequal distributions, since in rounds 4 through 7, 40 percent (12 out of 30) of the outcomes in which player 1 provided $q_1 = 0$ resulted in player 2 providing $q_2 = 0$ also. But in the best-shot game, in contrast to the ultimatum game, low offers by player 1 persisted, and the reluctance of player 2's to accept unequal distributions seems to have largely worn down by round 10. So the different behavior off the equilibrium path in the two games ultimately affected the behavior on the equilibrium path.

To summarize, results in the experimental literature indicate that ideas about fairness may play an important role in subjects' preferences or expectations, and that this may have significant

25. A related conclusion is suggested by the work of Forsythe, Horowitz, Savin, and Sefton [1992], one aspect of which compared ultimatum games with "dictator games," in which the first player's proposal was the outcome of the game (it could not be rejected by the second player). These two games yielded different distributions of first player proposals, suggesting that in the ultimatum game first players anticipate the reaction of second players. Similarly, see the different results for related bargaining games with extreme equilibrium predictions reported in Rapoport, Weg, and Felsenthal [1990]; Weg, Rapoport, and Felsenthal [1990]; Weg and Zwick [1990].

consequences for the outcome of a game. The evidence presented here suggests that the nature of these consequences may depend critically on traditional game-theoretic considerations concerning the anticipated behavior of other players (even when this behavior reflects concern for fairness). So this evidence suggests that descriptive theories of observable behavior in strategic situations will retain a clear game-theoretic character, even though players' motivations may be more complex than simple income maximization. However, the nature of these complex yet robust motivations cannot be ignored.

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