Fairness, Selfishness and Selfish Fairness: Experiments on Games with Unequal Equilibrium Payoffs[*]

by
James Andreoni
Department of Economics
University of Wisconsin
Madison, WI 53706

Paul M. Brown
Department of Economics
University of Massachusetts–Boston
Boston, MA 02125–3393

Lise Vesterlund
Department of Economics
Iowa State University
Ames, IA 50011

November 1997

Abstract: In games with unequal equilibrium payoffs, concepts of fairness and selfishness often clash. We structure the approach to fairness versus selfishness as a struggle between two forces that act on an individual's behavior. The two forces may be pushing behavior in the same direction in some cases but in opposite directions in others. Our goal is to collect the kind of information that may ultimately help formulate a full-blown model of how fairness and selfishness interact, both within an individual and across individuals in a given situation. We do this by examining three games of privately provided public goods. All of the games have virtually identical equilibria, but differ in the degree to which fairness can affect the outcome. We show that sometimes selfishness can overpower fairness, but at other times fairness can be so strong that even selfish players find it optimal to play fair.

---

[*] We are grateful to Jack Ochs and Larry Samuelson for helpful conversations, and to Isaac Rischall and Deena Ackerman for expert research assistance. Andreoni thanks the National Science Foundation for financial support.

Fairness, Selfishness, and Selfish Fairness: Experiments on Games with Unequal Equilibrium Payoffs

by James Andreoni, Paul M. Brown and Lise Vesterlund

1. Introduction

As economists, we treat the notions of self-interest and equilibrium as the primary determinants of behavior. In experiments self-interest is often equated with money-maximization, and equilibrium is taken to be Nash equilibrium and subgame perfection. However, when a game has a Nash equilibrium solution—assuming money-maximization—that entails very unequal payoffs among players, concerns of fairness appear to enter the decision process. The experimental evidence supporting this hypothesis is plentiful.[1] Just how fairness enters the decision process, or when fairness will overpower the gravity of money-maximizing equilibria, is not well understood.

In the studies of altruism and fairness to date, two things seem clear. First, in a static or single-shot setting it is reasonable to consider altruism as a commodity. Stated differently, it is possible to characterize subjects' choices as convex over the payoffs of all subjects with which they interact (Andreoni and Miller, 1996). Moreover, each individual has a potentially different notion of fairness or altruism. Second, fairness is defined uniquely for each situation. More precisely, in a dynamic or repeated setting concerns for fairness depend on the process of allocation, not simply on the allocation itself (Ochs and Roth, 1989). Hence, to describe fairness fully would require an introspective model of the "situation" that would capture the apparently complex calculation of when an allocation may be consistent with fairness.

In this paper we structure the approach to fairness versus selfishness as a struggle between two forces that act on an individual's behavior. The two forces may be pushing behavior in the same direction in some cases but in opposite directions in others. And when fairness and selfishness are opposed, sometimes selfishness can overpower fairness, but at other times fairness can be so strong that even selfish players find it optimal to play fair. Our goal is to collect the kind of information that may ultimately help formulate a full-blown model of how fairness and selfishness interact, both within an individual and across individuals in a given situation.

---

[1] See, Forsythe, et al., (1994) for an example of fairness in bargaining games, or see the extensive review of bargaining by Roth (1995), or the discussion by Guth (1995). For related effects in models of gift-exchange, see Fehr, Kirchsteiger and Reidl (1993), in centipede games see McKelvey and Palfrey (1992), in public goods games see Andreoni (1995) or Ledyard (1995), and for Prisoner's Dilemma see Andreoni and Miller (1993). For evidence on fairness in market transactions, see Kahneman, Kntesch and Thaler (1986). Also related are games on "trust," such as discussed by Battalio, VanHuyck and Walters (1995), and Berg, Dickhaut, and McCabe (1993).

We will look at three games that have (virtually) identical equilibria but which appear to differ in their notions of fairness as well as the way in which fairness affects the strategic behavior of selfish agents. We find that when a fair outcome is inefficient then the (subgame perfect) equilibrium of the game is a good predictor of actual behavior, and one can easily justify a self-interest assumption. However, if there exists a fair and efficient outcome, then the standard equilibrium prediction is misleading. The reason is not only that fairness-concerned subjects change behavior, but that their behavior dramatically changes the payoffs off the equilibrium path. This in turn generates a new set of best replies by the subjects who are motivated by self-interest alone. Hopefully, this paper will provide clues about how the relative strengths of these forces affect the choices subjects make.

2. Background

A popular game for illustrating the tension between selfishness and fairness is the ultimatum game. Guth, Schmittberger and Schwarz (1982), in early ultimatum game experiments, find behavior inconsistent with subgame perfection and conclude that the concept of equilibrium has little to say about how subjects actually behave, and conjecture that "subjects often rely on what they consider a fair or justified result." To counter this, Binmore, Shaked and Sutton (1985) explore a two-stage ultimatum game. Allowing players experience in the roles of both proposer and responder, they find that the equilibrium that results when assuming self-interest is indeed a good predictor. However, others that followed have argued that Binmore, et al., had accidentally designed a game in which the Nash prediction and the "fair" outcome were in fact the same (Guth and Tietz, 1990), undermining the application of subgame perfection for prediction in these games (Neelin, Sonnenschein and Spiegel, 1988).

A very careful and influential contribution to this discussion is given in Ochs and Roth (1989). They conduct two- and three-stage alternating offer bargaining games.[2] If player one makes an offer that is rejected, then the pie shrinks and it becomes player two's turn to make an offer to player one, and so on. The remarkable finding in these experiments is the existence of "disadvantageous counterproposals", that is, player two rejects an offer and then makes a counterproposal that yields

---

[2] They ran a four-by-two design, with four treatments of discount factors [$(\delta_1, \delta_2) = (0.4, 0.4), (0.4, 0.6), (0.6, 0.4)$, and $(0.6, 0.6)$,] and two treatments for the numbers of alternating rounds [either two or three rounds]. For instance, in a two-round game with discount rates $(0.4, 0.6)$ and a \$10 pie, if an offer made by player one was rejected, then in the second round player two would have a pie worth \$6 to him and \$4 to player one, which player two would propose to divide with player one.

him less than had he accepted the original offer by player one.[3] Viewed in terms of standard Nash equilibrium assumptions, this finding is quite puzzling. Ochs and Roth (1989, pp. 376), upon seeing the evidence, concluded that, "[t]he high frequency of disadvantageous counterproposals makes clear that there are nonmonetary arguments in the bargainers' utility functions. As this phenomenon seems to occur in the data of a variety of experiments, it merits serious attention."

What kind of clues for a better model have been left by their experiments? First, Ochs and Roth show that the observed mean agreements deviate from the equilibrium prediction in the direction of equal division. Thus it appears that both the proposers and responders seem to care about the distributions of payoffs. However, a simple model of altruism fails to explain the data. Many rejected offers were Pareto superior (in a monetary sense) to the counterproposals, which would appear inconsistent with purely altruistic motives. Instead, the fact that outcomes with Pareto inferior payoffs were "revealed preferred" by some responders means that some notion of relative payoffs is also likely to matter. As Ochs and Roth (1989, pp. 377) put it, "some component that measures 'unfairness' as deviations from equal division" is likely to enter individual preferences.

Prasnikar and Roth (1992) add more light as well as more mystery to the issue. They focus on the sequential aspects of games with unequal payoffs. They note that ultimatum and best-shot games are similar in that both have subgame perfect Nash predictions of unequal payoffs, but they differ in that this prediction is rarely observed in ultimatum games while it is a common outcome in best-shot games. Prasnikar and Roth (1992) conduct experiments on both games and draw a comparison.

They replicate the Harrison and Hirschleifer (1989) result that subgame perfect Nash equilibrium is a good predictor for best-shot games, and also the sundry results that proposers in ultimatum games usually offer 40–50 percent and responders often reject offers below 30 percent. In comparing the two games they conclude that the difference in observed behavior, despite the similarity of their equilibrium prediction, is in the payoffs off the equilibrium path. Specifically Prasnikar and Roth (1992) demonstrate that a deviation from the equilibrium will improve payoffs when playing the ultimatum game, while such a deviation will decrease payoffs in the best shot game.

Guth and Tietz(1990) propose an alternative explanation for the difference in observed behavior between the two games. Specifically they argue that the reason that an unequal payoff distribution is readily accepted in the best shot game and not in the ultimatum game is that there does not exist an efficient fair outcome in the best shot game.

In an attempt to test the counter hypothesis, Pasnikar and Roth develop a game

---

[3] Ochs and Roth also found disadvantageous counterproposals in the data of Guth, Schmittberger and Schwarz (1982), Binmore, Shaked and Sutton (1985) and Neelin, Sonnenschein and Spiegel (1988). See Ochs and Roth's Table 6.

which has an efficient fair outcome (similar to the ultimatum game), yet has payoffs off the equilibrium path similar to that of the best shot game. In this game, a seller auctions an item worth \$10 to each of nine buyers. The auction is by sealed bid. The result is nearly always a selling price of \$10, meaning that the seller makes a high payoff and not one of the buyers earns a thing. This finding provides additional support to Prasnikar and Roth's hypothesis that payoff off the equilibrium path is of crucial importance in determining the strength of the standard equilibrium prediction. They conclude that this finding does not mean that considerations of fairness do not play a role in determining the outcome of the game, but rather that such considerations interact with the strategic features of the game. Hence, Prasnikar and Roth expand the puzzle by finding a situation in which unequal payoffs are readily accepted, but in which equity (between the seller and the winner of the auction) is possible. They conjecture that the situation, in addition to the actual and the potential payoffs, can affect the outcome significantly.

While Prasnikar and Roth's results are provocative, making comparisons across such different games is difficult and imprecise. Ultimatum and best-shot games differ in payoff spaces, the choices available to subjects, and the framing of the decision. In addition, the auction game differs from the other two in the number of participants in any game—ten players in one auction versus two players in an ultimatum or best-shot game. Moreover, some have argued that the Nash outcome in the auction game can be seen as consistent with altruistic and fair motives by subjects (Levine, 1996). Hence, depending on the definition of fairness, selfishness and fairness may not be opposing forces in Prasnikar and Roth's auction game. The basic finding, however, that unequal payoffs are sometimes tolerated and sometimes not, is an important fact that needs to be understood. The conjecture by Prasnikar and Roth (that payoffs off-the-equilibrium-path is the key variable in understanding this puzzle) is persuasive, and deserves more careful scrutiny.

3. Toward a Formal Concept of Fairness

For simplicity, consider situations with only two individuals. Let π_1 be the payoff allocated to player one and π_2 be the payoff allocated to player two. Payoffs are drawn from a set Π of feasible payoffs, that is, $(\pi_1, \pi_2) \in \Pi$.

Look first at a single-shot situation, such as a dictator game. Then, as Andreoni and Miller (1986) have shown, it is possible to characterize altruism as simply preferences over the allocations to one's self and the other subject. That is, we can assume player one has preferences $u_1 = u_1(\pi_1, \pi_2)$, where the utility function u is continuous and quasi-concave. If, say, player one is given a chance to choose an allocation, he would choose $\pi_1$and π_2 to $\max_{\pi_1,\pi_2} u_1(\pi_1, \pi_2)$ subject to $(\pi_1, \pi_2) \in \Pi$. Depending on tastes for fairness or altruism, player one may not choose the maximum π_1 available.

This approach may be useful for describing simple settings, such as dictator games, in which one player has absolute control of the allocation. However, it is clearly insufficient for describing choices in ultimatum games, particularly the choice by the responder to accept or reject an offer. As Ochs and Roth (1989) make clear, preferences depend on more than simply the final allocation, but also depend in some unknown way on the means to that allocation.

A naive way to formulate concern over the means is to specify preferences as a function of the game itself. Let Γ be the set of games and $\gamma \in \Gamma$ be a particular game. Then we can imagine that individuals have preferences of the form $u_1 = u_1(\pi_1, \pi_2; \gamma)$. Hence, for two different games γ_1 and γ_2 and a particular payoff (π_1', π_2'), it may be that $u_1(\pi_1', \pi_2'; \gamma_1) > u_1(\pi_1', \pi_2'; \gamma_2)$, that is, under different rules, a certain allocation may have higher or lower utility. Furthermore, it may be possible that $u_1(\pi_1', \pi_2'; \gamma_1) > u_1(\pi_{1,}\pi_2; \gamma_1)$ and $u_1(\pi_1', \pi_2'; \gamma_2) < u_1(\pi_1, \pi_2; \gamma_2)$, that is, the ordering of two allocations may change as the rules of the game change. Finally, the games may also differ in the set of feasible payoffs Π.

The experiment that we present next is designed to gather more information on how utilities may depend on the circumstances of the game and on how the structure of the game leads self-interested players to take account of the game specific notion of fairness. Obviously, one study will not give us enough information to fully characterize these preferences, but may be a step toward learning what such a theory needs to capture.

4. Experimental Design

We consider a two-person model of public goods provision in which the equilibrium prediction entails very unequal payoffs to the two players. We explore three games with identical payoff tables, and virtually identical (subgame perfect) Nash equilibria. The three games will allow us to look at two issues regarding the ability and willingness to play Nash equilibria with unequal payoffs. First, we compare two games with identical payoff structures, but which differ in the players' abilities to commit to a free riding strategy. Next we compare two games in which players have equal ability to commit to a free riding strategy, but that differ in the payoffs off-the-equilibrium-path.

To motivate the game, consider the simple theoretical model in which two people provide a public good. Let x_i be consumption of a private good by i and let g_i be i's contribution to the public good. Each individual faces a budget constraint $x_i + g_i = m_i$. Define $G = g_1 + g_2$ as the total supply of the public good. For illustration, assume individuals each have utility functions $U_i = x_i + \alpha_i \ln G$, where $\alpha_1 > \alpha_2$. First, suppose that G is provided through simultaneous contributions. Then it is easy to verify that the best reply function for each player will be $g_i = \alpha_i - g_j$, $j \neq i$, that is, each player wants to bring the total contributions up to the level $G = \alpha_i$. But since $\alpha_1 > \alpha_2$ this means that the Nash equilibrium will be $g_1 = \alpha_1$, and $g_2 = 0$. Pareto efficiency, on the other hand, requires $g_1 + g_2 = \alpha_1 + \alpha_2$.

Next assume the game is played sequentially: player one moves first and player two moves second, and each player moves only one time. Now if α_1 and α_2 are not too different, the subgame perfect Nash equilibrium is for player one to commit to choosing $g_1 = 0$, leaving player two to choose $g_2 = \alpha_2$. Being in a position to commit to free riding, player one is clearly better off, and player two is worse off. In addition, since $\alpha_1 > \alpha_2$ the total supply of the public good is predicted to be lower than in the simultaneous case (Varian, 1994), but the set of Pareto efficient allocations remains unchanged.

Finally, consider one more variant on this game. This time define $G = \max\{g_1, g_2\}$. That is, now we have a best-shot game where the supply of the public good is determined by the maximum of the two contributions. Again, let player one move first. As before, the subgame perfect Nash equilibrium is $g_1 = 0$ and $g_2 = \alpha_2$. However, Pareto efficiency requires one of the players to contribute zero. Hence any allocation such that $g_i = 0$ and $\alpha_j \leq g_j \leq \alpha_1 + \alpha_2$, $j \neq i$, is Pareto efficient.

Notice that if subjects are assumed to be selfish then all three versions of this game have very similar equilibrium predictions, that is, one player provides all of the public good and earns a relatively low payoff, whereas the other player completely free rides and earns a relatively high payoff. In addition, selfishness implies that the sequential and simultaneous versions of this game have (virtually) identical payoffs both on- and off-the-equilibrium-path, but differ only in the ability of players to commit to free riding. The sequential and best-shot games have identical equilibrium payoffs under selfishness, and in both games the first contributor can commit to free riding. However, the off-the-equilibrium-path payoffs differ. Hence, comparing simultaneous to sequential play of the game will allow us to see how the ability to commit to free riding affects the outcome, and comparing the sequential to the best-shot games will allow us to see how off-the-equilibrium-path payoffs affect the willingness of players to accept Nash equilibria with unequal payoffs.

4.1. Experimental Parameters

The payoff table used in the experiments reported here is shown in Figure 1. It contains all of the incentives described in the theoretical model above. The game is played with two players. In the experiment, player one is named Red and player two is named Blue. Players must decide how many "Investment Units" to purchase. Investment units cost \$0.10 each. In Figure 1 the payoff from the public good to each subject depends on the total amount of investment units purchased. In the simultaneous public goods game, both players make their choice without knowing what the other will choose, while in the sequential public goods game, Red moves first.

As can be verified, the red subjects would, if acting alone, bring the total up to 9 investment units, while the blue subjects would bring the total up to 8. The Nash

Figure 1: Payoff Table for Public Goods Experiments

equilibrium in the simultaneous game is thus $g_1 = 9$ and $g_2 = 0$; Red earns \$0.35 and Blue earns \$1.25. In the sequential game the subgame perfect Nash equilibrium is nearly the opposite: $g_1 = 0$ and $g_2 = 8$, with payoff to Red of \$1.14 and payoff to Blue of \$0.35. In both cases it is Pareto efficient for $g_1 + g_2 = 17$.

Converting this game to the best-shot is trivial. Replace the heading on the first column in Figure 1 with the words "The greater of the investment units purchased by Red or Blue." Replace the heading above the third column with the"Additional return to Red from raising the greatest investment by 1," and make a similar adjustment to the final column heading. Hence, the exact same payoff table is used, but the definition of the public good changes from the total supply of investment units to simply the greater of those invested by the red and blue players. As above, the subgame perfect Nash equilibrium is $(g_1, g_2) = (0, 8)$ with payoffs again of \$1.14 and \$0.35. The best reply function here, however, is quite different. Red should always choose 0 units, but Blue's subgame perfect best reply is to choose $g_2 = 8$ if $g_1 \leq 2,$ and $g_2 = 0$ otherwise. Pareto efficiency requires either $g_1 = 0$, $8 \leq g_2 \leq 17$ or $g_2 = 0$, $9 \leq g_1 \leq 17$.

A session of our experiment went as follows. We recruited 14 subjects per session from economics courses at the University of Wisconsin. Subjects were randomly assigned to computer terminals in a computer classroom. All computers were separated by blinders. Subjects were given written instructions. The experimenter then read over the instructions with all participants. At that point the experimenter gave a quiz, which all subjects filled out on paper, asking them to calculate the payoffs in a specific example of the game. These were collected, and the example was gone over verbally by the experimenter. Half of the subjects were then randomly assigned to be Red players and half to be Blue. The subjects were informed that they would remain a red or blue player throughout the experiment.[4] The subjects then were walked through an example using the computer terminals, and again the outcome was explained to the subjects. Subjects then began the experiment. They played 14 iterations of the game. In each iteration they were randomly and anonymously paired with another subject, although we made sure that no one played another subject more than twice. Subjects' identities were never revealed to one another. After the 14 rounds, subjects participated in a "bonus round" which was designed to test their understanding of the game. We discuss this more later. Finally, the subjects' earnings for all 14 rounds were tallied and added to a \$3 show-up payment and earnings in the bonus round. Subjects were paid anonymously with cash in "payment envelopes" which were handed out by subject number. We ran three sessions of each

---

[4] Note the many important differences from another paper on sequentially provided public goods by Coats and Gronberg (1996). Their experiments considered a "provision point" model of a discrete public good, whereas ours is a continuous public good. In addition, our subjects remain in the same role throughout the experiment, whereas theirs change roles each round.

of the three games, for a total of 126 subjects.[5] The experiment typically lasted less than an hour, and subjects made an average of \$12.85 (standard deviation of \$2.10, maximum of \$19.25, and minimum of \$5.00). A copy of the instructions for the sequential game are found in the appendix.

4.2. Predictions

Note the key features of the experimental design. If all agents maximize their own payoff, then all three games have virtually identical equilibrium predictions. The simultaneous and sequential games have identical payoff-possibilities but differ in the ability of players to commit to free ride and to punish selfish opponents. Differences in play between them can be attributed to commitment and punishment rather than to altruism. The sequential and the best-shot games allow equal ability to commit and punish, but differ in the ability of players to cooperate. That is, the set of payoff possibilities for the best-shot game is a subset of those for the sequential game, even though the Nash equilibria are identical. Hence, differences in play—including commitments and punishments—can be ascribed to differences in off-the-equilibrium-path payoffs, that is, to the lack of a fair allocation in the best-shot game.

Our framework for a formal concept of fairness gives us a number of predictions. First, compare the sequential to the simultaneous game. In both games the preferences for fairness, $u(\pi_1, \pi_2)$, and the ability to choose a fair outcome, Π, are equal. Hence, two players wishing to have a fair allocation will be equally able to do so in both the sequential and simultaneous games. What about motives for selfishness? Notice that in both games the best reply to a fair contribution (of say 4 or 5 investment units) is also a fair contribution (of 4 or 5 units). In the simultaneous play game, a player who may simply wish to play the Nash best-reply will instead appear to play fairly if he believes enough others are playing fairly as well. In the sequential game, however, such a person could commit to playing the equilibrium if he is a

---

[5] Notice that while Harrison and Hirschleifer's design has many features in common with our design, it is different in several important ways. First, their payoff function is the same for both players, whereas ours is asymmetric. This means that our games have strict predictions in equilibrium, for both sequential and simultaneous play, whereas Harrison and Hirschleifer's only has strict predictions for sequential play. Second, Harrison and Hirschleifer had players randomly changing between three different public goods games each round. Hence, a player could be in a best-shot in one round and a summation game the next. Moreover, subjects also randomly switch roles each round, so a person could be a first-mover in one round but a second mover the next. Our experiment maintains greater control by having subjects play in only one game and in only one role. Finally, Harrison and Hirschleifer have a very small number of subjects; only six subjects (three pairs) play a best shot game for six periods. By contrast, we have 32 subjects in each of our conditions (126 subjects in total) and each subject plays the public goods game for 14 rounds. Other limiting aspects of the Harrison and Hirschleifer experiments have also been discussed by Prasnikar and Roth (1992).

player one (Red in the experiment). What would prevent him from doing so would be fear of retribution by player two (Blue in the experiment). To the extent that some second players are also selfish, and hence unwilling to punish, playing sequentially will give some first players greater latitude to free ride. As a result, we should observe behavior closer to the equilibrium prediction in the sequential game than in the simultaneous game.

Next compare the best-shot game to the sequential game. Here there is equal ability for a selfish player one to commit to free riding, and equal opportunity for a player two to punish selfishness. One major difference is the set of payoff possibilities. In the sequential game Π is convex, while in the best-shot game it is a non-convex subset of the Π of the sequential game. Two players who would have preferred a fair allocation in the sequential game, for example a G of 8 supplied by 4 units each, will be unable to attain this in the best-shot game. The non-convexity of the payoff space makes it all the more likely that two people with preferences for fairness, $u(\pi_1, \pi_2)$, will nonetheless find the corner solution—that is the subgame perfect equilibrium—optimal. In other words, fairness will have a small role, or perhaps no role, in the best-shot game, and the standard equilibrium prediction under selfishness is likely to prevail.

5. Results

Figures 2, 3 and 4 illustrate the results of the simultaneous, sequential and best-shot games respectively. Over the 14 rounds, the simultaneous game produces an average G of 8.55, sequential produces 7.15, and best-shot 6.86. However, over the last 5 rounds, the average level of G is very similar across all three games: 7.16 for sequential, 6.55 for simultaneous and 7.33 for best-shot.

When we explore the individual contributions, however, the differences in the games become apparent. Figure 2 shows that the average choices for the two players are almost identical every round in the simultaneous game, despite the Nash prediction that player one would choose 9 and player two would choose 0. Although outcomes in 10 of the 14 rounds show more giving by player one on average, the difference is not significant. Looking at individual subjects, a rank-sum test reveals no significant difference between the choices of the two types of players.[6]

Figure 3 gives the same information for the sequential game. In this game, the subgame perfect equilibrium is that player one chooses 0 and player two chooses 8. Here we do indeed see more separation between the players, with more given to the public good on average by player two, and less by player one. While the difference is

---

[6] A rank-sum U-test comparing average choices by subjects over all 14 rounds yields a z-score of $z = -0.553$. Looking at only the last 5 or last 3 rounds yields $z = -1.044$ and $z = -0.623$ respectively. A description of this test can be found in John E. Freund, 1971, pp. 347–49.

Figure 2: Simultaneous Public Goods Game, $G = g_1 + g_2$.

clearly larger than in the simultaneous game, again the difference is not significant, and play of the subgame perfect equilibrium is still fairly uncommon.[7]

Finally, Figure 4 shows the results for the best-shot game. While the two players struggle early on, by midway through the game, most interactions between subjects actually occur at the subgame perfect equilibrium. Over the last five rounds, 61 percent of all best shot games are at the subgame perfect Nash equilibrium. This compares with 17 percent of the sequential plays and only one percent of the simultaneous plays.

Looking across games also generates some interesting comparisons. First compare the simultaneous to sequential games. Looking at each player one's role and using a non-parametric rank-sum test, we see that over all rounds the simultaneous first players do indeed give significantly more than sequential first players ($z = 2.113$). However, by the end of the experiment the difference has largely disappeared (for instance, $z = 1.270$ for the last 3 rounds). Perhaps this pattern can be explained by the behavior of the second players. Comparing the simultaneous and sequential

---

[7] The rank-sum U-test yields $z = 1.484$ over all rounds, $z = 1.019$ for the last 5 rounds, and $z = 1.635$ for the last 3 rounds.

Figure 3: Sequential Public Goods Game, $G = g_1 + g_2$.

second players, the overall difference is not at all significant ($z = -0.075$), and the difference stays insignificant throughout the experiment ($z = 0.780$ for the final 3 rounds). Hence, it appears that the ability of a player two to stick to a fair allocation in the sequential game—as defined by the simultaneous outcome— seems to force the hand of his partner to also mimic the fair choices of simultaneous game. In other words, when player one tries to use his ability to commit to free riding early on in the experiment, player two can use his punishment power and preferences for fairness to discipline player one into playing fairly.

Next, compare the sequential to the best-shot games. The first players do indeed give significantly more in the sequential game. Interestingly, however, this difference only emerges later in the experiment. In the first 5 rounds of the game, the sequential and best-shot first players behave similarly, with a $z = 0.955$. By the end of the experiment, however, the difference is highly significant, with $z = 2.465$ for the last 5 rounds, and $z = 2.629$ for the last 3 rounds.[8] The second players, however, behave differently throughout. Over the first 5 rounds the best-shot second players give

---

[8] Over all 14 rounds, the difference is marginal, with $z = 1.736$.

Figure 4: Best-shot Public Goods Game, $G = \max\{g_1, g_2\}$.

(marginally) significantly more, with $z = 1.90$; the difference remains significant with $z = 3.308$ and $z = 2.855$ for the last 5 and 3 rounds respectively.[9] What appears to be happening is that the first players in both games try early on to use their power to commit to free riding. However, only in the best-shot game do the second players allow them to do so.

Let us explore these hypotheses further by looking more closely at the moves of the individual players. Table 1 shows the average choices of all players in the simultaneous public goods game for both sessions. Here we see that the choices of players are very equitable. Both on average and at the median both players give similar amounts to the public good. Moveover, earnings are similar. A player one earns \$9.37 on average, while a player two earns \$9.79.[10]

Table 2 shows the choices by only the first players in the sequential public goods game. The Nash equilibrium prediction is for first players to choose zero. No subject

---

[9] Over all 14 rounds, $z = 2.428$.

[10] This and all subsequent references to earnings by subjects include just the earnings in the public goods game, and do not include the \$3 show-up fee or the earnings in the bonus round.

chose this for all rounds, while only three do for the last 5 rounds, and only five do for the last 3 rounds. The choice of the average player one is 2.8 over the last 5 rounds and 2.6 over the last 3. The median choice over the last 3 rounds is 2.

Table 3 looks at the best-shot game. It tells a slightly different story. The first players in the best-shot game are much more likely to choose the Nash equilibrium of zero. Over the last 5 rounds, ten of 21 choose $g = 0$ all 5 rounds, and sixteen of 21 choose less than 1 on average. By the last 3 rounds thirteen of 21 choose zero, and the same sixteen choose less than 1 on average. Over all rounds, the average player one chooses 2.36, with a median choice of 1. By the end of the game, however, most choices are zero, as predicted. In fact, more than half of all subjects choose $g_1 = 0$ for all rounds after 11, and sixteen of 21 choose zero in the final round—twice the number in the sequential public goods game.

Five best-shot players are worth special note. Player 3 in session 1 and player 3 of session 3 both choose 9 throughout most of the experiment. A post-experiment questionnaire reveals that these subjects mistakenly inferred (the first after being punished early on) that as the first player, they were in the disadvantaged position. Since they choose 9 and get 0 as a reply for the rest of the game, they learn nothing to disabuse them of this belief.[11] Subject 5 in session 2 settles on giving 1, but then gives 2 in the final round, and subject 9 of session 1 gives 1 each round, beginning in round 6. In a post-experiment questionnaire, these two express a desire to appease the second-movers by sacrificing a token amount. Finally, subject 7 in session 2 alternates between 0 and 9. The post-experiment questionnaire revealed that this person too is trying to share the burden with the second-movers, but clearly understands the Nash equilibrium.

How do the second players respond? Table 4 shows the choices of the second players in the sequential game. Here the prediction is that the second players would choose $g_2 = 8 - g_1$ (or 0 if this is negative). Over the last 5 rounds, seven of the players consistently follow this best reply. Subjects 8 and 14 of session 3 appear to understand the best reply, but deviate somewhat—subject 14 brings the total to 9 in two rounds, and subject 8 chooses $g_2 = 20$ in round 14 after following the Nash best-reply from rounds 4 to 13. Counting these, nine of 21 follow the best reply. Over the last 3 rounds, 11 players choose the best reply. While the median outcome over the last 5 rounds is indeed the equilibrium of $G = 8$, the median choice of these second movers is only 3, indicating a great many "equitable" outcomes.

Compare these to choices in the best-shot game, shown in Table 5. Over the last 5 rounds, fourteen of 21 subjects choose the best reply, and over the last 3 rounds, 16

---

[11] This is suggestive of a notion put forth by Fudenberg and Levine (1997) on how subjects learn only the part of the game tree they experience. Here a bit more experimentation with free riding may have taught these two subjects to behave differently.

make this choice.[12] The five subjects who refuse to choose the best reply include two people who were severe-punishers, subject 8 of session 1 and subject 6 of session 2. Subject 14 of session 1 appeared to totally misunderstand the task, and always chose to match what the first-mover had chosen.[13] Finally, subjects 8 and 14 of session 3 choose the best reply in four of the last five rounds. In the final round subject 8 chooses 20 in reply to a 0, while subject 14 chooses 0 in reply to 0. If we count these as best-repliers too, then 18 of 21 subjects choose the subgame perfect best reply by the end of the experiment. Notice too that the median choice of second-movers in the best-shot game is 8, as is predicted by subgame perfection.

It appears that the choices of the best-shot game are, as in previous experiments, quite close to the subgame perfect Nash equilibrium prediction. In contrast, the sequential game is quite far from it, despite the similarity of the equilibria. In fact, looking at the distribution of moves by second players, the rational reply by first players is indeed quite different across the two experiments. Table 6 reports a frequency of choices by player one, the mean and median reply by player two and the subsequent average payoffs. A curious result from Table 6 is that the return to player one of choosing 0 is lower than for choosing 1, but the payoffs from choosing 1, 2, 3 or 4 are quite similar. It appears as if player two forces player one to be indifferent between contributing 1 and 4 (thereby making cooperation more attractive), but punishes for choosing 0. Perhaps, as a result, choosing 3 or 4 is a popular choice among first players.

Table 7 provides the same information on the best-shot game. Here choosing $g_1 = 0$ is clearly the most highly rewarded strategy of the first players. Moreover, replies by the second players largely follow the best reply pattern, where $g_2 = 0$ if $g_1 > 2$, but $g_2 = 8$ otherwise. As seen in Table 5, this is especially true in the later rounds. Hence, since player two is less likely to punish, player one is more likely to free ride.

A final way to make this point is given in Table 8. Here we indicate the punishments by second players conditional on the choice of the first players. Define a punishment as a choice of $g_2 \in [0, 2]$ and define a strong punishment as a $g_2 = 0$. Suppose first that player one chooses the subgame perfect Nash equilibrium strategy of $g_1 = 0$. The conditional probability that this is answered with a punishment of either kind is more than twice as high in the sequential game as in the best-shot game, with the difference growing as the game progresses. If instead we condition on $g_1 \in [0, 2]$, then a similar, albeit less extreme pattern emerges. An interesting observation here is that as we move from $g_1 = 0$ to $g_1 \in [0, 2]$ we see that the probability of

---

[12] Over the last 5 or 3 rounds, some subjects show an average G above 8, either 8.2 or 8.3, in sessions 1 and 3 respectively. These subjects used the Nash best-reply but were paired with the one Player one in each session who consistently chose 9.

[13] The post-experiment questionnaire reveals that this subject could not correctly calculate the earnings of the two subjects in the experiment.

Figure 5: Simultaneous Public Goods, Frequency of Outcomes in the Last Five Rounds

punishment falls somewhat in the sequential public goods game, but rises somewhat in the best-shot game.[14]

The results uncovered in these tables can be illustrated rather starkly by comparing the distributions of (g_1, g_2) from the last five rounds of each game. Figure 5 shows the outcomes in the simultaneous public goods game. Here we see play is rather diffuse, with the equilibrium of (9,0) drawing scant attention. Hence, it is clear that equilibrium is not an organizing principle in this game. However, since behavior seems to lack any clear pattern, even fairness is hard to discern. Figure 6 gives the same information for the sequential public goods game. Now the data begin to produce some regularities. We see that low contributions of g_1 are likely to be punished, while higher contributions are met with the best reply of $g_2 = 8 - g_1$. What is also clear from Figure 6, however, is that generous moves are rarely rewarded. Hence,

---

[14] Although there is clearly not enough information here to support any hypothesis, it almost appears as if the best-shot players are punishing the first-movers for wasting money rather than for free riding.

Figure 6: Sequential Public Goods, Frequency of Outcome in the Last Five Rounds

the sequential game produces an interesting asymmetry in that selfishness is often punished while unselfishness, such as $g_1 \geq 6$, is met with the rationality rather than a reward.

Figure 7 illustrates the outcomes for the best-shot game. Here the results are rather dramatic. Subjects in the player two role are largely following the strategy of $g_2 = 8$ if $g_1 \leq 2$, and $g_2 = 0$ otherwise, and a substantial majority of all outcomes are at the equilibrium. Now both punishments and rewards are absent, equilibrium is clearly an organizing principle, and no fairness of any kind is appears to be important.[15]

---

[15] One may ask whether the differing complexities of the games affected the results. To examine this we administered a test question at the very end of the experiment. Subjects were told to make choices for both Red and Blue players and to calculate payoffs for each. We then fliped a coin to determine for which role subjects would be paid. Of the 42 subjects in each game, three or four subjects per game made errors in calculating payoffs in the bonus round. Hence, differing errors by subjects are not likely to explain the results.

Figure 7: Best Shot, Frequency of Outcomes in the Last Five Rounds

6. Discussion and Conclusion

We presented three different games, each with virtually identical equilibrium predictions, but found different behavior associated with each. The first, a simultaneous public goods game, gave fairness the greatest chance to be expressed, and indeed, the play in this game was consistent with fairness. The second, a sequential public goods game, gave just as much opportunity for fairness as the first game, but by allowing one player to commit to the free riding equilibrium, the game strengthened the force of money-maximization in counteracting fairness. The second game, as predicted, found behavior moving toward the standard equilibrium prediction, but the subgame perfect outcome was still rarely observed. We saw that many first players tried early in the experiment to take advantage of their first-mover status, but punishments by second players drew them away from the equilibrium. In fact, playing fairly by choosing $g_1 = 4$ was more profitable to the average player one than choosing the equilibrium $g_1 = 0$. Hence, one could say that in this game it was selfish to play fair.

The third game was a best-shot game. This game had the same subgame perfect prediction as the sequential game, but denied subjects the chance to reach a fair outcome in which both benefit. Here the choices were overwhelmingly at the subgame perfect level. As in the sequential game, the first players began by trying to exploit their first-mover advantage. The difference between this and the former game is that in this game the second players allowed them to do so. As a result, selfishness and subgame perfection were powerful predictors in the best-shot game.

Can we interpret these results in terms of our framework for fairness? Suppose people do in fact have preferences of the form $u(\pi_1, \pi_2; \gamma)$. The differences between the game situations γ of the simultaneous and sequential games is simply the order of play, since the choices available for the subjects, Π, are the same. If enough people care sufficiently about fairness, then an allocation of, say, $g_1 = g_2 = 4$ seems like a reasonable outcome regardless of the order of play. We in fact see that this was largely the case—choices in the sequential and simultaneous games are not significantly different by the end of the experiment. And, moreover, this result seemed to be driven by second players who refused to accept unfair free riding by first players. Hence, changing the game to sequential from simultaneous weakens the effect of fairness somewhat, but does not eliminate it.

Looking at the best-shot verses the sequential games, we see other differences. In both games the first-mover can commit to free riding. The rules are similar to the sequential game, but the set of choices for the two players, Π, is quite different. In particular, the possible payoffs in the best-shot are contained in those of the sequential game, $\Pi_{bs} \subset \Pi_{seq}$. Moreover, Π_{bs} is noncovex. Thus, it is easy to imagine that investments of $(g_1, g_2) = (0, 8)$ would maximize $u_1(\pi_1, \pi_2; \gamma)$ subject to $(\pi_1, \pi_2) \in \Pi_{bs}$ even though investments of $(4, 4)$ might maximize $u_1(\pi_1, \pi_2; \gamma)$ subject to $(\pi_1, \pi_2) \in \Pi_{seq}$. Likewise, for player two the investments of $(0, 8)$ might be the best alternative under Π_{bs}, but not under Π_{seq}. Hence, as seen by this framework, the same preferences and rules could lead to differences in behavior between the two games.

What does this study tell us about constructing a more specific theory of fairness and equilibrium? First, by comparing two games which differ only in off-the-equilibrium-path payoffs, it confirms the conjecture of Prasnikar and Roth (1992) that such non-equilibrium payoffs do indeed matter. Hence, a theory must acknowledge how utility—that is, tastes for fairness—not simply payoffs, may be affected at all possible elements of Π. Second, this study shows that the rules γ matter some, even when they don't affect the equilibrium prediction. For example, allowing moves to be sequential rather than simultaneous generates some difference in behavior. Initially, this threatens the fairness of the allocation, and indeed many more players act selfishly. However, because many of the second players are willing to punish, the first players find that selfishness does not pay as well as fairness. Hence, fairness prevails in the struggle, although not as well as in the simultaneous game. In order to refine the framework for fairness, more studies need to be done which systematically alter the environments of subjects, by manipulating both payoff spaces and the rules of the game in order to identify how preferences are shaped and how these two factors influence outcomes of games.

TABLE 1

Choices in the Simultaneous Public Goods Game, $G = g_1 + g_2$

		Average g_1				Average g_2		
	Subject Number	all rounds	last 5 rounds	last 3 rounds	Subject Number	all rounds	last 5 rounds	last 3 rounds
Session 1	1	2.36	1.6	1.7	2	4.29	2.8	2.7
	3	3.58	2.2	1.7	4	2.79	2.6	2.7
	5	3.36	2.2	1.7	6	3.07	0.8	0.0
	7	3.64	2.8	2.0	8	5.50	1.6	0.0
	9	5.21	4.0	3.0	10	5.93	4.4	7.0
	11	5.57	4.2	3.3	12	4.36	2.4	2.3
	13	2.71	2.2	2.3	14	4.71	4.0	4.0
Session 2	1	1.86	0.0	0.0	2	3.39	0.8	1.3
	3	5.64	3.4	5.0	4	2.50	4.0	4.0
	5	4.14	4.6	5.7	6	4.64	4.2	4.3
	7	2.29	1.6	1.3	8	3.64	2.0	1.3
	9	6.29	4.2	5.3	10	8.00	8.0	8.0
	11	4.71	4.4	4.3	12	2.57	2.0	2.3
	13	4.57	3.4	1.7	14	4.86	3.6	3.7
Session 3	1	4.36	4.0	3.7	2	0.72	0.6	1.0
	3	3.5	6.0	5.3	4	0.00	0.0	0.0
	5	4.43	3.8	2.3	6	7.36	7.8	8.3
	7	7.71	7.2	8.7	8	1.93	1.6	1.7
	9	3.36	3.4	3.0	10	5.00	5.4	5.7
	11	7.64	7.6	8.0	12	3.14	2.8	2.3
	13	6.36	8.2	8.3	14	8.00	8.0	8.0
Mean		4.44	3.9	3.7		4.11	3.3	3.4
Median		4	4	3		4	3	3

TABLE 2

Choices by First-Movers in Sequential Public Goods Game

	Subject number	Average g_1 all rounds	last 5 rounds	last 3 rounds	Round adopted $g_1 = 0$	Earnings
Session 1	1	2.14	2.8	2.7	-	10.87
	3	6.00	5.6	5.0	-	8.10
	5	3.36	2.6	2.3	-	9.70
	7	4.71	4.6	5.3	-	9.70
	9	3.00	3.0	3.0	-	10.67
	11	0.50	0.6	0.3	13	13.19
	13	1.36	0.2	0.0	11	7.68
Session 2	1	0.71	0.0	0.0	4	7.84
	3	1.07	0.0	0.0	4	7.38
	5	2.57	0.4	0.0	12	8.50
	7	4.14	4.2	4.0	-	10.79
	9	3.50	3.4	3.7	14	8.52
	11	5.21	6.4	6.7	-	6.07
	13	1.36	1.8	2.3	-	8.28
Session 3	1	0.79	0.0	0.0	3	12.56
	3	3.79	3.6	4.0	-	11.05
	5	2.14	2.4	2.3	-	10.55
	7	4.21	3.2	1.3	-	7.62
	9	5.14	4.0	4.0	14	9.74
	11	5.64	4.8	4.0	-	8.82
	13	4.21	5.4	3.7	-	9.77
Mean		3.12	2.8	2.6		9.40
Median		3	3	2	-	9.70

TABLE 3

Choices by First-Movers in Best-Shot Game

	Subject number	Average g_1 all rounds	Average g_1 last 5 rounds	Average g_1 last 3 rounds	Round adopted $g_1 = 0$	Earnings
Session 1	1	2.79	0.8	1.0	-	8.72
	3	7.50	9.0	9.0	-	4.59
	5	0.79	0.0	0.0	7	11.67
	7	0.86	0.2	0.0	11	11.46
	9	1.86	1.0	1.0	-	8.73
	11	1.57	0.0	0.0	4	10.02
	13	1.50	0.0	0.0	4	11.30
Session 2	1	1.86	0.2	0.0	12	8.78
	3	1.14	0.0	0.0	7	12.14
	5	2.57	1.2	1.3	-	9.54
	7	4.29	3.4	2.7	14	9.13
	9	0.71	0.0	0.0	4	13.77
	11	1.36	0.8	0.3	14	9.90
	13	0.93	0.0	0.0	7	11.50
Session 3	1	2.29	0.0	0.0	6	10.93
	3	9.00	9.0	9.0	-	4.90
	5	0.64	0.0	0.0	2	14.39
	7	0.71	0.0	0.0	4	12.35
	9	3.29	4.8	1.7	13	10.50
	11	1.00	0.0	0.0	7	11.16
	13	3.00	0.4	0.0	12	10.45
Mean		2.36	1.5	1.2		10.68
Median		1	0	0	11	10.50

TABLE 4

Replies by Second-Movers in Sequential Public Goods Game, $G = g_1 + g_2$.

		Average g_2			Average G		
	Subject number	all rounds	last 5 rounds	last 3 rounds	last 5 rounds	last 3 rounds	Earnings
Session 1	2	5.93	5.0	4.3	8.0	8.0	8.55
	4	3.79	1.4	1.0	3.2	3.7	5.94
	6	4.21	2.0	2.3	6.0	7.7	8.75
	8	5.00	4.2	5.0	8.0	8.0	9.27
	10	2.21	3.0	2.0	6.0	4.0	7.89
	12	5.14	6.2	7.0	8.0	8.0	9.16
	14	3.93	4.4	4.3	6.4	5.3	8.30
Session 2	2	1.57	1.6	1.3	5.4	2.3	8.08
	4	4.07	2.6	2.3	3.4	2.3	6.03
	6	4.07	5.6	6.7	6.4	8.0	4.91
	8	6.00	7.2	6.7	8.0	8.0	7.79
	10	2.43	1.8	2.7	7.6	12.0	8.60
	12	3.21	2.0	1.3	4.8	4.3	8.36
	14	3.36	1.8	2.0	3.2	2.7	5.74
Session 3	2	4.07	4.2	5.7	8.0	8.0	11.07
	4	4.86	4.0	5.7	8.2	8.0	10.58
	6	2.57	1.8	2.7	5.2	6.0	8.15
	8	7.57	9.6	11.7	10.4	12.0	7.56
	10	1.64	2.0	1.7	4.8	4.7	6.87
	12	4.86	3.0	3.3	8.2	8.0	10.29
	14	4.00	5.2	4.7	8.4	8.0	10.86
Mean		4.02	3.7	4.0	6.5	6.62	8.63
Median		4	3	4	8	8	8.30

TABLE 5

Replies by Second-Movers in Best-Shot Game, $G = \max\{g_1, g_2\}$.

		Average g_2			Average G		
	Subject Number	all rounds	last 5 rounds	last 3 rounds	last 5 rounds	last 3 rounds	Earnings
Session 1	2	6.36	6.4	5.3	8.2	8.3	7.47
	4	5.71	6.4	5.3	8.2	8.3	7.86
	6	4.64	6.4	5.3	8.2	8.3	9.25
	8	1.57	1.4	2.3	3.4	2.7	5.12
	10	5.71	6.4	8.0	8.2	8.0	8.06
	12	5.86	8.2	8.3	8.2	8.3	6.75
	14	2.29	2.2	3.0	2.2	3.0	1.62
Session 2	2	4.71	8.0	8.0	8.0	8.0	7.17
	4	5.71	8.0	8.0	8.0	8.0	7.78
	6	1.86	0.0	0.0	0.4	0.3	3.89
	8	4.29	5.8	5.3	7.4	8.0	4.59
	10	6.86	8.0	8.0	8.0	8.0	6.68
	12	6.36	6.4	8.0	8.2	8.0	5.88
	14	6.86	8.0	8.0	8.0	8.0	6.37
Session 3	2	5.14	4.8	5.3	10.4	8.0	9.16
	4	4.86	6.4	5.3	8.2	8.0	6.68
	6	4.93	8.8	5.3	8.2	8.0	8.57
	8	5.43	6.4	12.0	10.6	12.0	5.99
	10	5.71	6.4	8.0	8.2	8.0	7.60
	12	5.79	6.4	5.3	7.4	7.0	7.72
	14	4.14	6.4	5.3	6.4	5.3	7.15
Mean		4.99	6.1	6.2	7.3	7.27	6.73
Median		8	8	8	8	8	7.15

TABLE 6
Returns to Player One Moves in the
Sequential Public Goods Game

	Reply g_2		$G = g_1 + g_2$			Average Payoff to	Average Payoff to
g_1	Mean	Median	Mean	Median	N	Player 1	Player 2
0	4.74	8	4.74	8	78	0.66	0.19
1	5.18	7	6.18	8	33	0.79	0.38
2	4.05	4	6.05	6	22	0.68	0.50
3	4.30	5	7.30	8	44	0.75	0.63
4	4.07	4	8.07	8	45	0.73	0.73
5	3.00	3	8.00	8	18	0.64	0.85
6	2.57	2	8.57	8	14	0.59	0.93
7	3.44	5	10.44	13	16	0.62	0.96
8	1.33	0	9.33	8	6	0.44	1.11
9	1.50	0	10.50	9	10	0.46	1.19
10	2.25	2	12.25	12	4	0.50	1.24
13	1	1	14	14	1	0.32	1.48
15	3	3	18	18	1	0.35	1.47
17	0	0	17	17	1	0.10	1.73
20	0	0	20	20	1	−0.06	1.85

TABLE 7

Returns to Player One Moves in the Best-Shot Game

	Reply g_2		$G = \max\{g_1, g_2\}$			Average Payoff to	Average Payoff to
g_1	Mean	Median	Mean	Median	N	Player 1	Player 2
0	6.84	8	6.83	8	140	0.97	0.30
1	5.89	8	6.00	8	57	0.76	0.28
2	4.69	8	5.38	8	16	0.57	0.32
3	2.50	0	4.60	3	10	0.39	0.44
4	1.67	0	4.67	4	6	0.29	0.56
5	0.00	0	5.00	5	2	0.25	0.80
6	2.88	1	6.50	6	8	0.36	0.70
7	1.80	0	7.20	7	5	0.35	0.88
8	0.29	0	8.00	8	7	0.34	1.12
9	0.69	0	9.00	9	39	0.35	1.17
10	0	0	10	10	1	0.34	1.32
11	3	3	11	11	1	0.32	1.09
12	0	0	12	12	1	0.29	1.46
19	0	0	19	19	1	0.00	1.81

TABLE 8

Punisments by Second-Movers to Low Contributions to First-Movers

	Prob. $g_1 = 0$	Prob. $g_2 = 0$ given $g_1 = 0$	Prob. $g_2 \in [0, 2]$ given $g_1 = 0$	Prob. $g_1 \in [0, 2]$	Prob. $g_2 = 0$ given $g_1 \in [0, 2]$	Prob. $g_2 \in [0, 2]$ given $g_1 \in [0, 2]$
Seqential Public Goods:						
All Rounds	26.5	30.8	43.6	45.2	18.8	37.6
Rounds 1-7	22.5	30.3	42.4	40.1	20.3	33.9
Rounds 8-14	30.6	31.1	44.4	50.3	17.0	40.5
Best Shot:						
All Rounds	47.6	11.4	13.6	72.4	12.7	18.8
Rounds 1–7	30.0	13.6	15.9	59.9	14.8	23.9
Rounds 8–14	65.3	10.4	12.5	85.0	11.2	15.2

Appendix:
Subjects' Instructions for the Sequential Public Goods Game

The University of Wisconsin
Department of Economics

WELCOME

This experiment is a study of group and individual investment behavior. The instructions are simple. If you follow them carefully and make good investment decisions you may earn a considerable amount of money.

The money you earn will be paid to you, in cash, at the end of the experiment. A research foundation has provided the funds for this study.

HOW YOU MAKE MONEY

First, you will get $3.00 put into your earnings account just for being willing to participate. The money you make from your investment decisions will be added to this account as the experiment proceeds.

Your identity will be kept private throughout the experiment. Neither the people running the experiment nor the other participants will ever know your name, nor will they be able to link you with any of the decisions made in the experiment.

Your decisions will be recorded by the computer. At the end of the experiment you will receive your cash payment in a sealed envelope so that no one but you knows how much you have earned.

Please do not talk to any other participant during the experiment.

THE TWO INVESTORS

In this experiment you will make a series of 14 investment decisions. For each investment decision you will be randomly paired with one other participant. Your investment returns will depend on the investment decisions that you and the other participant make.

IMPORTANT NOTICE: For each investment decision you will be *randomly* paired with a different participant. You will never play against the same participant two times in a row.

In each investment decision, one participant will be known as the BLUE Investor, and one participant will be known as the RED Investor. We will tell you at the start of the experiment whether you will be a BLUE investor or a RED investor. Your color will be the same throughout the experiment.

YOUR INVESTMENT DECISION

Each of the two investors can purchase Investment Units. Investment units cost 10 cents per unit. For instance, if you purchase 6 units, we will subtract \$0.60 from your investment earnings. Each participant can purchase anywhere from 0 to 20 units.

What you earn from the investment will depend on the number of units purchased by you and the other participant. The two investors, however, will not earn the same amount of cash from the investment. Your earnings will depend on whether you are the BLUE investor or the RED investor.

The table on the following page can help you calculate the earnings from the investment. As you can see in the table, earnings depend on the TOTAL number of investment units purchased by both participants.

MAKING THE INVESTMENT CHOICES

For every investment decision, the RED investors will always make their investment decisions first. When all RED participants have entered their decisions into the computer, the computer will randomly match each RED participant with a BLUE participant. The choice of the RED investor will then be revealed to the BLUE investor. The BLUE investors will then be asked to make their investment choices, each knowing the number of investment units already purchased by the RED investor in their pair. When all the BLUE participants have entered their decisions, the computer will calculate the returns for both investors.

[The Table shown in Figure 1 appears on the following page of the Instructions.]

CALCULATING YOUR EARNINGS FOR EACH INVESTMENT CHOICE

The best way to explain how to use the table to calculate your earnings is with some examples.

Example 1. Suppose both investors purchased zero investment units. Then both investors would get a return of \$0 and spend nothing on investment units, hence earning nothing for this investment decision. If either investor had purchased one unit, at a cost of \$0.10, RED's return from the total investment would go up by \$0.15, and BLUE's would go up by \$0.16.

Example 2. Suppose the RED investor chooses to purchase 5 investment units, and the BLUE investor purchases 2 units. Then the total units purchased is 5 + 2 = 7. Turning to the row labeled 7 in the table, we see that the RED investor will earn \$1.03 from the investment and the BLUE investor will earn \$1.04 from the investment. However, the RED investor must pay 5 × \$0.10 = \$0.50 for his 5 investment units, yielding net earnings of \$1.03 – 0.50 = \$0.53. Likewise, the BLUE investor must pay 2 × \$0.10 = \$0.20 for his 2 investment units, yielding net earnings of \$1.04 – 0.20 = \$0.84. Notice, we can also use the table to see how investors can change their earnings. If either investor had purchased one more unit, at a cost of \$0.10, RED's return from the total investment would go up by \$0.13, and BLUE's would go up by \$0.11.

INFORMATION TO YOU

After all participants have made their decisions, the computer will inform you of the outcome of your investment. You will be told the investment decisions, the investment returns, and the net earnings after paying for investment units of both investors. No one will be told of the investments or earnings of other participants in the experiments.

YOUR CASH EARNINGS

Your investment earnings will be tallied by the computer. At the end of the experiment your earnings from investments will be added to the $3 starting payment to determine your total cash earnings. This will be paid to you in a sealed pay envelope at the end of the experiment. Neither the people running the experiment nor the other participants will ever be able to tie you to any of your investment decisions or to your investment earnings.

Your decisions and earnings are strictly private information.

SUMMARY

The important things to remember are:

1. Investment Units cost \$0.10 each, which will be subtracted from your Investment Return.
2. Investment Returns depend on the total amount invested by both Red and Blue investors.
3. The Red investor moves first. After learning what the Red investor chose, the Blue investor moves second.
4. For each round you will be randomly matched with a new partner.
5. There are 14 rounds in total.
6. Your earnings and choices are all secret, private information.

References

Theorem 1 Andreoni, James, "Cooperation in Public Goods Experiments: Kindness or Confusion?", *American Economic Review*, 85, 1995b, 891–904.

Andreoni, James and John H. Miller, "Rational Cooperation in the Finitely Repeated Prisoner's Dilemma: Experimental Evidence," *Economic Journal*, 103, 1993, 570–585.

Andreoni, James and John H. Miller, "Giving According to GARP: An Experimental Study of Rationality and Altruism," working paper, University of Wisconsin, 1996.

Battalio Ray, John VanHuyck and M. Walters, "Commitment versus Discretion in the Peasant Dictator Game," *Games and Economic Behavior,* 10(1), July 1995, 143-170.

Berg Joyce, John Dickhaut, and Kevin McCabe, "Trust, Reciprocity, and Social Norms," working paper, February 1993.

Binmore, Ken, Avner Shaked and John Sutton, "Testing Non-cooperative Bargaining Theory: A Preliminary Study," *American Economic Review,* 75, 1985, 1178-80.

Coats, Jennifer C. and Timothy J. Gronberg, "Provision of Discrete Public Goods: An Experimental Investigation of Alternative Institutions," Unpublished Manuscript , October 1996.

Davis, Douglas D. and Holt, Charles A., *Experimental Economics*, Princeton University Press, 1992.

Fehr, Ernst, Georg Kirchsteiger, and Arno Riedl, "Does Fairness Prevent Market Clearing? An Experimental Investigation," *Quarterly Journal of Economics*, CVII, 1993, 437–460.

Forsythe, Robert, Joel Horowitz, N.S. Savin, and Martin Sefton, "Fairness in Simple Bargaining Games," *Games and Economic Behavior*, 6, 1994, 347–69.

Freund, John E., *Mathematical Statistics,* Second Edition, Englewood Cliffs, N.J.: Prentice Hall, 1971.

Fudenberg, Drew and David K. Levine, "Measuring Player's Losses in Experimental Games," *Quarterly Journal of Economics,* CXII, May 1997, 507–536.

Guth, Werner, "On Ultimatum Bargaining Experiments—A Personal View," *Journal of Economic Behavior and Organization*, 27, 1995, 329–344.

Guth, Werner, R. Schmittberger and B. Schwartz, "An Experimental Analysis of Ultimatum Bargaining," *Journal of Games and Economic Behavior,* 3, 1992, 367–88.

Guth, Werner, and Reinhard Tietz, "Ultimatum Bargaining Behavior: A Survey and Comparison of Experimental Result," *Journal of Economic Psychology,* 11, 1990, 417–49.

Harrison, Glen and Jack Hirschleifer, "An Experimental Evaluation of the Weakest Link, Best Shot Models of Public Goods," *Journal of Political Economy*, 97, 1989,201–25

Hoffman, Elizabeth, Kevin McCabe and Vernon Smith, "Preferences, Property Rights and Anonymity in Bargaining Games," *Games and Economic Behavior*, 7, 1994, 346–80.

Kahneman, Daniel, Jack L. Knetsch, and Richard Thaler, "Fairness as a Constraint on Profit Seeking: Entitlements in the Market," *American Economic Review*, 76, 1986, 728–41.

Ledyard, John O., "Public Goods: A Survey of Experimental Research", in J.Kagel and A.E. Roth, eds., *Handbook of Experimental Economics*, Princeton University Press: Princeton N.J., 1995.

Levine, David K., "Modeling Altruism and Spitefulness in Experiments," UCLA working paper, 1996.

McKelvey, Richard D. and Thomas R. Palfrey, "An Experimental Study of the Centipede Game," *Econometrica*, 60, 1992, 803–836.

Neelin, Janet, Hugo Sonnenschein, and Matthew Spiegel, "A Further Test of Noncooperative Bargaining Theory," *American Economic Review,* 78, 1988, 824-36.

Ochs, Jack and Alvin E. Roth, "An Experimental Study of Sequential Bargaining," *American Economic Review*, 79, 1989,355–84.

Prasnikar, Vesna and Alvin E. Roth, "Considerations of Fairness and Strategy: Experimental Data from Sequential Games," *Quarterly Journal of Economics*, August, 1992, 865–88.

Rabin, Matthew, "Incorporating Fairness into Game Theory and Economics," *American Economic Review*, 83, 1993, 1281–1302.

Varian, Hal R., "Sequential Provision of Public Goods," *Journal of Public Economics*, 53, 1994, 165–86.