7/28/05

W01-3

Institutions for Facilitating Cooperation: Evidence from Economics Experiments on Public Goods, Common-Pool Resources and Team Production Environments

By

James Walker
Department of Economics
Workshop in Political Theory and Policy Analysis
Indiana University

January 14, 2003

Prepared for presentation, St. Vincent College, Latrobe, PA, March, 2001

I. Introduction: Experimental Methods and the Decision Problem

Over the past 30 years, applied microeconomics has seen an explosion in the use of experimental methods as a tool for observing economic behavior. Economic experiments serve as a complement to field research using, allowing the researcher to create and control key theoretically based rules of decision making and incentives. Experimental economic environments are designed to create the incentive systems of alternative market and nonmarket economic institutions, allowing the researcher to examine propositions related to static equilibrium theory, dynamic learning models, and individual choice theory. Economic incentives are most often created via salient cash rewards designed to induce the incentive properties of the economic problem under investigation.

This paper deals with behavior in an institutional setting referred to as a social dilemma. We begin by considering the following resource allocation problem that might be implemented in an experimental laboratory decision-making experiment.

Each of four individuals, making decisions anonymously and simultaneously, receives an endowment of $20. Each individual can choose to keep their $20, or allocate some or all of the $20 to a group account. For each dollar allocated to the group account, each individual receives $.50. Under one scenario this decision problem might be played only once. Alternatively, the game could be repeated several times, with the same group or varying groups of decision makers.

Three primary questions arise. (1) How does this game setting parallel "naturally occurring decision problems"? (2) What are the predictions of economic theory for this decision situation? (3) What behavior do we observe when such games are implemented in the experimental laboratory?

The decision situation described above has strategic elements that play an integral role in understanding decision making in numerous economic situations, including the voluntary provision of public goods, team production, and the extraction of many natural resources. In this paper, we first look at these issues from the perspective of economic theory, and recent modifications to that theory. Following this discussion, we investigate behavior in experimental settings designed to implement the strategic nature of this type of problem, as well as institutions that may alter decision making.

Public Goods, Common-Pool Resources, and Team Production

In the classic case of a pure public good, provision of the good is nonrival and nonexcludable. That is, consumption by one individual does not subtract from the feasible consumption of others and the opportunity to consume is not constrained by whether the individual has paid for the right. The decision problem discussed above parallels the idea of a pure public good. Contributions by any individual to the group account provide a public good to each group member, a public good equal to the marginal payoff of a dollar contributed to the group account.

The decision problem can also be seen as a metaphor for some types of common-pool resource problems. Similarly, interpreted in a particular way, the situation can be seen as a type of team production problem. A common-pool resource is defined as a good that is rival but nonexcludable. Interpret the problem above in the following way. Each dollar contributed to the group account creates a common-pool resource worth $2.00. Each individual receives a 1/n share, $.50, of the group good, whether they contribute or not. In this sense the good is rival. If there was one less group member, each individual in the group would have received $2.00/3 = $.67. Likewise, the situation illustrates a team production problem where individual team members share equally in productivity of the team, regardless of their individual efforts. That is, these team members face a particular type of common-pool resource problem.

Important to notice in these examples is the subtle difference between the interpretation of this problem as a pure public good or a common-pool resource. The key lies in the impact of varying group size. In the case of a pure public good, one can increase group size and each member continues to receive the same marginal return from the group good, $.50. That is, there is nonrivalry. In the case of a common-pool resource problem, increasing group size implies rivalry, each member's 1/n share is reduced proportionately.

Finally note that these are particular "stylized" versions of public goods and common-pool resource/team production problems. For example, one could certainly imagine public goods settings where individuals are heterogeneous in the return they receive from the public good and/or face diminishing marginal returns from the public good. Fisher et al. (1995) and Laury, Walker, and Williams (1999) consider these two issues. Further, the common-pool resource/team production problem investigated here is a particular institutional instance of these types of problems. In particular, here we consider the case where individuals receive a 1/n share of the resource. Clearly, many instances occur where individual returns depend on individual efforts/investments in utilizing a resource (see Ostrom, Gardner, and Walker, 1994).

II. Game Predictions

Predictions from Economic Theory

The strategic game discussed above can be modeled using the tools of noncooperative game theory. Assume each individual's utility from playing the game depends strictly on money earnings in the game and is increasing in wealth. The game is one of complete information and the game-theoretic prediction is that each individual should allocate no money to the group account. The reasoning is simple. Each dollar allocated to the group account comes at a cost of $1 and a marginal return to the individual making the contribution of $.50. The individual is said to have a dominant strategy of no contribution.

What if the game is played repeatedly, a finite number of times? If all players are rational in the sense of making choices that maximize their earnings, and they all believe all others are rational in this sense, the Nash equilibrium for this game continues to be no individual making allocations to the group account. The logic follows from backward induction. In the final period, each individual would have a dominant strategy to allocate zero to the group account. Taking this into account, each individual can deduce that their payoff maximizing strategy in the next-to-last round is to allocate nothing to the group account. Following this logic for all rounds, leads to the result that in every round, each subject's income-maximizing strategy is to place nothing in the group account.

Note that this prediction of zero allocations to the group account emphasizes the dilemma individuals face in this type of decision making. If individuals follow their best strategic response to this problem, based on individual income maximization, gains from cooperation are foregone. In fact, in the situation described above, the losses are extreme. That is, the outcome that would maximize total group income would be if all individuals allocated all resources to the group account.

Alternative Predications

As we will discuss below, whether this game is played once or repeated a finite number of times, behavior does not always follow the prediction of the economic theory discussed above. Beginning with the seminal work of Kreps et al. (1982), economic theorists have suggested alternative ways one might model decision making in this environment; relaxing assumptions that subjects might have about the behavior of other subjects and/or relaxing the assumption that subjects' preferences can be represented as a strict one-to-one mapping of income into utility.

Kreps et al. describe a setting in which subjects believe there is the possibility that some subjects are not rational, in the sense of playing the Nash equilibrium strategy defined above. They show that once the assumption of complete rationality is removed, the door is open to strategies and equilibria in which all subjects may allocate some resources to the group account, except in the very last period. The sequential equilibria depend on the possibility of a player type who may respond to previous cooperative plays by playing cooperatively in the future.

Somewhat similar reasoning is proposed in the approach that is offered by Isaac, Walker, and Williams (1994). They suggest that subjects may see the game as a forward-looking problem, dismissing the assumption of backward induction. In their approach to this game, subjects are seen as decision makers who believe their current decisions may impact the decisions of other decision makers in the next decision round, an assumption closely related to one based on norms of reciprocity. Their approach to modeling the choice of the decision maker has three principle components: (1) the assumption that individual i believes his decisions have signaling content to others who will respond in a reciprocal manner; (2) a benchmark earnings level for measuring the success of signaling; and (3) the formulation of a subjective probability function for evaluating the likelihood of success. The principal conjectures of this model are the following: (1) an individual will be more likely to signal in those experimental conditions in which their subjective probability is greater that others will respond positively to signals and (2) signals (allocations to the group account) are positively related to group size and the marginal benefits from the group good. If multiple-stage signaling is allowed, then the following conjecture seems reasonable: as the final round approaches, the expected gains from signaling diminish. Thus, in contrast with a purely adaptive or learning model where the number of rounds completed is central to behavioral dynamics, this expanded forward-looking approach suggests that the number of rounds remaining is an important determinant of behavior in the current round.

More recently, some theorists have suggested an alternative modeling approach based on relaxing the assumptions of how individual payoffs are mapped into utility. In particular, several theorists have proposed that subjects may have utility functions that incorporate the payoffs of other players. An obvious candidate is that subjects may be altruistic. In this case, the utility a given subject receives from an allocation to the group account will have a negative component related to their loss of earnings and a positive component related to the gains in payoffs to other subjects (see Andreom, 1993, Palfrey and Prisbrey, 1997, and Bolton and Ockenfels, 2000, and Ahn, 2000. In related work, an alternative assumption of inequality aversion has been suggested by Fehr and Schmidt, 1999. With this approach, the decision maker must weigh gains in their own earnings against (relative to) those of others. Just how these two approaches affect equilibrium play in the game situation described here depends on specifics of how the alternative utility functions are modeled. In both cases, however, the door is open to observing behavior in which subjects cooperate in allocations to the group account, weighing such decisions against the opportunity cost of foregoing the returns from allocations to their own private account.

III. Behavior in Experimental Settings

The discussion below brings together several summary observations from research conducted by the author with various colleagues and by several other researchers who have recently focused on the question of team production issues. The observations are based on an organization in which the institutional setting is changed to examine alternative mechanisms that may foster cooperation.

Baseline Behavior: The Stark Institutional Setting

A common view expressed in most economic textbooks is that the degree of free riding occurring in public goods settings will increase with increases in group size. The question is whether this view is founded in well-documented behavior. The experiments discussed below were designed to shed light on this issue.

The presentation of results begins with observations reported in Isaac, Walker, and Williams (1994). Subjects in this setting faced the following decision problem referred to in the literature as the Voluntary Contribution Mechanism (VCM). Each individual was allocated 50 tokens per decision round. Tokens could be allocated to an individual account that paid the subject $.01 per token. Alternatively, tokens could be allocated to a group account that paid each group member $.003 or $.0075 per token, depending upon the experimental design. In the discussion below, the results are organized around the concept of marginal per capita return from the group account relative to the private account (the MPCR). In these experiments, this is simply .3 and .75. Groups were of size 4, 10, 40, or 100. Note that in the game setting illustrated in the introduction, the MPCR was .5.

Unless otherwise specified, subjects knew the experiment would last 10 decision rounds, that all decisions were anonymous, and that each subject would be paid in private at the end of the experiment.[1] Between decision rounds, subjects learned of the total allocations to the group account in the previous round and their earnings for the previous round. The information conditions were such that no subject could deduce the individual earnings of other group members. Finally, group composition was constant between decision rounds.

Summarized below are three general findings from this research: (1) allocations to the group account are inversely related to MPCR; (2) holding MPCR constant, allocations to the group account are positively related to group size; and (3) increasing group size in conjunction with a decrease in MPCR leads to lower allocations to the group account, a lower level of efficiency in provision of the pure public good.

Figure 1 displays evidence related to each of these three findings. Reported are mean levels of allocations as a percentage of optimum across decision rounds. The top left-hand panel displays results from parametric conditions where N=10 and MPCR=.3 or MPCR=.75. Note the general increase in allocations to the group account for the MPCR=.75 condition. The top right-hand panel displays results from conditions where MPCR=.3 and N=10 or N=100. Contrary to many of the broad generalizations that are found in textbook discussions of public goods, holding MPCR constant, one observes an increase in allocations to the group account (less free riding) with the larger group size. However, evidence is also found to support some textbook discussions of the free-rider phenomena, in which authors explicitly illustrate group size effects with specific arguments related to decreases in the marginal value of the public good in conjunction with increases in group size (crowding effects) and/or illustrations of large group, public goods settings with inherently small marginal valuations. The bottom panel displays results from the conditions where N=10, MPCR=.3 and N=40, MPCR=.O3. With an increase in group size, the value of the public good at the margin decreases to group members. In this case, one observes a validation of the proposition that an increase in group size leads to a decrease in the level of public goods provision.

The experiments reported next were all conducted with N=10 and MPCR=.3O. There are two design changes relative to the previously reported experiments. First, subjects were provided with a handout explicitly stating the conditions in which (1) an individual receives the maximum possible earnings, (2) an individual receives the minimum possible earnings, (3) the group as a whole receives the maximum possible earnings, and (4) the group as a whole receives the minimum possible earnings. Second, the number of decision rounds varied from 10 in three experiments to 40 in two experiments to 60 in one experiment. The subjects in the 40-round experiments were drawn from a pool of subjects with experience. The subjects in the 60-round experiment were drawn from the two 40-round experiments.[2]

Figure 2 summarizes the results from these additional experiments. The top panel displays the sequence of mean allocations to the group account from a series focusing solely on the effect of additional payoff information. The bottom-left panel reports the results of two experiments with 40 decision rounds and the additional payoff information. These experiments exhibit a pattern of allocations to the group account in which group allocations begin at a mean of 57.5% and decay slowly (but not monotonically) to a mean of 6.8% by round 40. The bottom-right panel reports the results of one experiment with 60 decision rounds and the additional payoff information. In this experiment, group allocations begin at 51% of total endowment and decay slowly (but not monotonically) to 19.2% by round 60.

These experiments supplement earlier results in several interesting ways. Even with a richer information environment, highly experienced subject groups continue to follow a pattern of behavior inconsistent with the predictions of the complete information Nash model. Further, the rate of decay of allocations to the group account is inversely related to the number of decision rounds. For example, compare rounds 8-10 in the 10-round experiments to rounds 8-10 in the 40 and 60-round experiments. Or, compare rounds 35-40 in the 40-round experiments to rounds 35-40 in the 60-round experiments. Clearly, the rate of decay is faster the shorter the time horizon of the experiment. This result is inconsistent with backward induction models, and purely adaptive or learning models based on the number of rounds completed. This aspect of the VCM data is consistent with a forward-looking modeling approach based on the potential gains from cooperation.

Summarizing:

- Depending upon specific parameterizations, replicable behavior is observed where allocations are very near the predicted outcome of zero allocations to the group account or are significantly above zero allocations to the group account.
- There is considerable heterogeneity in decisions across subjects and across decision rounds.
- Allocations to the group account are either unaffected by MPCR or are inversely related to MPCR.
- Holding MPCR constant, allocations to the group account are either unaffected by group size or are **positively** related to group size.
- Increasing group size in conjunction with a **sufficient** decrease in MPCR leads to lower allocations to the group account.
- There tends to be some decay (but generally incomplete) to the predicted outcome of zero allocations to the group account.
- Even with a richer information set regarding the implications of alternative allocation decisions, highly experienced subject groups continue to follow a pattern of behavior generally inconsistent with the predictions of the complete information Nash model.
- Inconsistent with models of learning, the rate of decay of allocations to the group account is inversely related to the number of decision rounds.

The experiments reported above describe behavior in a stark environment allowing no explicit mechanisms for promoting cooperation. In the next sections, we turn to institutional settings where mechanisms are created for explicit attempts at fostering cooperation.

Face-to-Face Communication

When face-to-face communication is allowed, subjects are brought together in a common area in the laboratory environment. They are told they can discuss anything they choose, except that: (1) no private information can be exchanged (such as individual decisions in past rounds), (2) no physical threats can be made and no side-payments can be discussed, and (3) their discussions will be monitored for compliance to the first two conditions.

Figure 3 summarizes the results from the first study that was completed (Isaac and Walker, 1988), in which all groups were of size N=4. In this figure, means are reported across three treatment conditions: (1) NC/NC, where no communication was allowed; (2) NC/C, where 10 initial rounds of no communication were followed by 10 rounds in which communication was allowed between every decision round; and (3) C/NC, where 10 initial rounds with communication were followed by 10 rounds with no communication.

Summarizing the results from these experiments:

- In the NC/C treatment, communication has an immediate positive effect on allocations to the group account and that effect increases with repetition.
- In the C/NC treatment, communication has a significant positive effect on communication and there is a strong hysteresis effect in the rounds that follow where no communication is allowed. In fact, in the four experiments that are included in this condition, in only one was there significant decay in group allocations. In three of the four experiments, the groups reached efficiencies of 98% or higher in 30 of 30 rounds.

In addition to the results reported above, Isaac and Walker also draw the following two conclusions.

- In experiments in which subjects receive asymmetric endowments of tokens and communication is allowed, the levels of allocations to the group account in experiments with symmetric endowments tend to dominate those under conditions of asymmetric endowments.
- In a more complex environment in which group size was increased to N=8 and subjects faced a declining MPCR for allocations to the group account, communication significantly increased allocations to the group account. However, in this more complex setting: (a) agreements were less explicit, (b) allocations were not sustained at high levels (the mean decreased from almost 100% down to near 40% by the last period, and (c) post experiment interviews suggested that non-compliance subjects rationalized that the optimum could be reached without their cooperation.

Finally, Isaac and Walker (1991) investigate a setting where communication is available to the subjects, but at a cost. Before the start of the experiment, it was explained that the subjects would have the opportunity to meet before each decision round, if they "purchased" the opportunity to do so. The opportunity to communicate was funded as a provision point public good. Groups were all of size N=6. If at least four individuals chose to contribute $.10, the group was allowed to meet. In effect, this setting created a second-order dilemma game where individuals must expend resources to provide a mechanism that may alter the strategic nature of a first-order dilemma game. The results from these set of experiments can be summarized as follows:

- Of six groups, only two succeeded in funding the communication opportunity in the first round. By the fourth round, however, all groups were successful.
- The groups used the opportunity to communicate to make allocation commitments to the group good and to solve the second-order efficiency problem, not having to fund the

opportunity to meet every round. That is, the subjects explicitly discussed this problem and made multi-period commitments.

- In the decisions that followed the first opportunity to communicate for each group, average efficiency in providing the public good was 91%. There was, however, an end-period effect in which efficiencies dropped significantly in four of six experiments.

Finally, it is worth noting the results from a study by Schmitt, Swope, and Walker (2000) that investigates face-to-face communication in a setting in which communication is allowed among only a subset of the subjects. Their study investigates behavior in a common-pool resource social dilemma setting in which subjects return from the resource depends on their own investment in harvesting the resource, and marginal returns are declining in aggregate group harvesting. So, one important aspect of this environment is that reductions in harvesting by some group members lead to opportunities for others.

In summary, these authors find that a lack of complete agreement among all group members can significantly reduce the impact of communication as a mechanism to facilitate cooperation. Outsiders respond strategically to reductions in appropriation by cooperating group members. Members of the communicating group deviate from agreements more frequently when monitoring is imperfect and over appropriation can be blamed on outsiders. Groups that are allowed to communicate anticipate the potential problems and have difficulty reaching agreements or committing to a specific appropriation rule.

Experiments with Rewards and Sanctions

Based on the research reported in Sefton, Shupp, and Walker (2000), we introduce here experiments that maintain the same basic structure as the baseline VCM environment, except that a second stage is added to the decision problem where individuals may reward or sanction other group members.

In many team situations, workers repeatedly interact while observing the efforts of their co-workers, and an individual worker has rich opportunities for reacting to a co-worker's behavior in ways that may impose costs or benefits on both parties. There is abundant anecdotal evidence that individuals sanction those who engage in selfish activities at the expense of other group members. For example, people who violate social norms are often ostracized. Similarly, there is strong anecdotal evidence that people are prepared to make sacrifices to help others on a quid pro quo basis.

Given this evidence, the possibility that individuals will sanction or reward other group members, based upon their contributions, in a public goods/team production laboratory setting seems real. In turn, the possibility of receiving such sanctions or rewards may affect contributions. Such contributions could be viewed as a response to the threat of "negative reciprocation," in the case of sanctions, or the promise of "positive reciprocation," in the case of rewards. The experiments reported below compare the effectiveness of such negative and positive reciprocation in maintaining contributions to public goods.

The decision-making phase of the experiments consisted of two sequences often rounds (Sequence I and Sequence II). The structure of Sequence I and Sequence II was explained to the subjects prior to beginning Sequence I. All groups consisted of four group members.

In all sessions, each round in Sequence I corresponded to a standard VCM game. At the beginning of the round, each subject was endowed with six tokens to be allocated between their private account and the group account. For each token placed in his or her private account, a subject received 10 cents. For each token placed in the group account, every group member received 5 cents (an MPCR = .5). After all subjects had made their decisions for the round, they were informed of the aggregate allocations to the group account, the allocation of each member of their group to the group account, and their own earnings for the round. Individual decisions were not linked to subject identifiers, however, and the order in which other group member's decisions were presented was randomized. Thus, it was impossible for subject-specific reputations to develop.

The nature of Sequence II varied across four treatments: SANCTION, REWARD, COMBINED, and BASELINE.

In the SANCTION treatment, the first stage of the round involved a VCM game identical in structure to that used in the first sequence of rounds. In the second stage of the round, each subject was endowed with six additional tokens, which could be allocated to a private account, from which the subject earned 10 cents per token, or used to sanction other group members. The computer screen informing subjects of the individual decisions of other group members was used for imposing sanctions. Alongside each of the other group member's decisions, subjects could indicate how many of their six tokens they wished to use to sanction the group member making that decision. Thus, subjects could sanction on the basis of current round decisions, but would not be able, for instance, to sanction subjects for their earlier round decisions. For each token used to sanction another group member, that group member's earnings were reduced by 10 cents. The cost to the sanctioner was the foregone earnings from their own private account. A feature of the sanction treatment ,therefore, is that each token used for sanctioning reduces group earnings by 20 cents.

The REWARD treatment was identical to the sanction treatment, except that instead of using tokens to sanction other group members, subjects could use tokens to reward other group members. In a similar fashion to the sanction treatment, subjects using tokens to reward other group members incurred a cost in the form of foregone earnings. However, for each token used to reward a group member, that group member received 10 cents. Thus, rewards constituted a pure redistribution of earnings, and had no direct effect on total group earnings.

The COMBINED treatment allowed both rewards and sanctions. Again, using a screen that listed first-stage decisions, a subject could allocate tokens to a private account, yielding 10 cents per token, or could allocate tokens to the other group members, foregoing the private account earnings. Tokens allocated to another group member could be used to either sanction them, in which case that subject's earnings were reduced by 10 cents, or reward them, in which case that subject's earnings were increased by 10 cents.

Finally, in the BASELINE sessions all twenty rounds consisted only of a VCM game. To enhance the degree of parallelism between the BASELINE and other treatments, the twenty rounds of the BASELINE sessions also include two sequences often rounds, and in each round of the second sequence subjects received six additional tokens in their private accounts.

Figure 4 shows how the use of sanctions and rewards changes over time. In the SANCTION treatment, subjects begin the second sequence often rounds by allocating on average 1.9 (31%) of their second stage endowment of tokens to sanctions, but this percentage falls to 16% by the final round. The decline in the use of rewards is more striking. Tokens used for rewarding others falls sharply, from 2.5 (41%) in round 11 to 3% in the final round of the REWARD treatment. The right-hand panel of Figure 4 describes the use of rewards and sanctions in the COMBINED treatment. Again, subjects seem to initially prefer using rewards to sanctions. In round 11, 2.5 (42%) of tokens are allocated to rewards and only 0.5 (8%) to sanctions. However, this pattern does not survive. In the final round, only 8% of token endowments are used for rewarding other subjects, and 10% for sanctioning.

Figure 5 displays average group allocations across all twenty rounds. The data for Sequence I (rounds 1 to 10) show little difference between the four treatment conditions. As shown, the time trends of average group allocations diverge across treatments in Sequence II. Most notably, average group allocations in the REWARD, SANCTION, and COMBINED conditions move away from the BASELINE condition over the course of Sequence II, with the COMBINED treatment showing the largest increases in group allocations. In addition, the data reveal an interesting dynamic in the REWARD, treatment. In the last round of Sequence II, group allocations in the REWARD treatment fall to a level below that of the BASELINE condition.

Recall, however, that rewards and sanctions have different impacts on earnings distributions. Sanctions represent a net loss, while rewards simply redistribute earnings. Figure 6 displays earnings as a percentage of maximum across rounds for each treatment, focusing on Sequence II. There is an upward shift in earnings in the REWARD and COMBINED treatments, and a downward shift in earnings in the SANCTION treatment. The most striking comparison reflects the improvement in earnings between round 11 and round 20 in the SANCTION treatment.

Over all, these experimental results support the supposition that there may exist a behavioral asymmetry in how reward and sanctions can be used to facilitate cooperation. The use of sanctions may be necessary to promote cooperation initially, but the threat of sanctions may be sufficient to sustain cooperation. It may be, however, that a reward system requires continued use of rewards. Behaviorally, the subjects in our experiments did not appear to be able to sustain such behavior in the latter rounds of these experiments.

Sanctions and Group Size Effects

In an experimental study parallel to the work presented here, Jeff Carpenter (2000) examines the question of how the impact of sanctioning systems in team production settings might be dependent upon group size. Carpenter's work examines whether there is evidence of a pure group size effect and/or whether there might exist a group size effect if one assumes that larger groups face the problem of incomplete information on the part of all group members about the actions of all other group members. That is, as group size increases, monitoring of all individuals by all other individuals in a group may be inhibited.

Carpenter examines groups of size 5 and 10. In groups of size 5, there are four treatment conditions related to monitoring: (1) no monitoring, (2) full monitoring (every group member sees the contributions of every other group member), (3) half monitoring (each group member monitors the contributions of two other members and (4) single monitoring (each group member monitors the contributions on only one other group member). In groups of size 10, the only condition examined was full monitoring.

Carpenter's results can be summarized as follows:

- When there is full monitoring, large groups sanction more than small groups, "...members tend to sanction transgressors without considering the fact that others might also punish." Free riders are sanctioned on average 50% more in large groups.
- The level of punishment decreases with the level of monitoring. On average, in the single monitoring condition free riders receive sanctions that are only 38% of those received by free riders in the full monitoring conditions.

Thus, similar to the results related to group size effects in pure public goods settings, Carpenter's work identifies behaviorally how changing group size in team production/sanctioning settings may have opposing effects — the effects dependent on how the setting changes as group size changes.

External Sanctioning and Reward Systems

In a related study, David Dickinson (2000) examines the question of whether sanctioning mechanisms, in comparison to reward systems, imposed by an employer are better or worse at improving team productivity. In both mechanisms investigated by Dickinson, the employer is able to fully monitor team member contributions. Team members vary in their ability to contribute and this leads to two types of mechanisms (absolute and relative). In the absolute prize condition, the team member making the highest contribution wins the prize. In the absolute sanction condition, the team member making the highest contribution is the only team member not to receive a penalty. In the relative prize and relative sanction conditions, the individual making the highest contribution is determined relative to ability.

The results of Dickinson's study can be summarized as follows:

- All four mechanisms increase team production relative to a baseline with no such mechanisms.

- The Relative prize mechanism increases contributions more than the other three conditions. There is no clear significant difference, however, between the prize and penalty mechanisms.

IV. Conclusions

Collective-action problems offer a unique and challenging setting for social scientists interested in the linkages between theory, institutions, and behavior. Evidence from field and experimental studies provides support for three fundamental propositions:

- Without some form of coordination or organization to enable individuals to agree upon, monitor, and sanction contributions to the provision of a public good, the good is *under-provided.*
- Face-to-face communication in small group settings has an immediate efficiency-enhancing effect on behavior. Subjects openly use communication to find a joint strategy, to build agreement to using that strategy, and to verbally sanction noncompliance (even when there is insufficient information to identify actual defectors).
- Reward and sanctioning alternatives are utilized by subjects, in settings where they may not be expected to, but the overall efficiency-enhancing attributes of such mechanisms are still under debate.

The results presented here, and elsewhere in similar research, raise the question of how one might develop behavioral models to understand such behavior, when in many situations, models based on purely selfish behavior predict no, or much less, cooperation. As discussed by Ostrom, Gardner, and Walker (1994), one approach for explaining observed patterns of cooperation relies on notions of incomplete information and interprets the game as if it were infinitely repeated. This approach relies on incomplete information surrounding the termination point for the experiment. However, Ostrom, Gardner, and Walker (1994) offer a final interpretation based on bounded rationality. They propose two principles based on the evidence gathered. The first principle is that agents use communication or other mechanisms to reach and support agreements. The second principle is that agents will find and adopt simple agreements. In a communication session, subjects tend to do two things: (1) focus on an agreement approximating the group maximum and (2) formulate a simple symmetric plan of play for the repeated game, where failure to cooperate by some is met with future, income reducing, non-cooperation by all. Game theory based on complete rationality requires that players have a strategy, a complete plan of play for every contingency. Selten, Mitzkewitz, and Uhlich (1997) argue that players are basically reactive in nature. Suppose that players in a communication phase have reached agreement on how play should proceed. As long as play proceeds according to the agreement, there is no need to react. Reaction is only called for when something unexpected happens, in particular, a defection from the agreement. The first principle that subjects use when communicating about equilibrium selection—find a simple symmetric solution—gives the subjects a reference point, their agreement, for reactions. The second principle—simplicity—reinforces the agreement as a reference point and suggests the form that reactions may take to deviations from the agreement. This way of looking at cooperation is supported by the view expressed by Fehr and Gachter (2001). In their study, they model costly sanctions as a behavioral response based on emotions. Beyond the strict pecuniary properties of games, subjects enter a game with "norms" of acceptable behavior. When someone violates such behavior they are sanctioned and the degree of sanction is based on the size of the deviation.

In summary, the behavior reported here leaves several puzzles for behavioral scientists. First, how does one come to grips with the high level of heterogeneous play observed across subjects and across subject groups? Secondly, how does one design institutions that not only promote cooperative behavior, but do so in the long run and in a cost efficient way? Experiments, in combination with analysis of field settings, create opportunities for continuing to probe these complex behavioral puzzles.

Endnotes

1. In some cases subjects made decisions in classes where payoffs were in extra-credit points. See Isaac, Walker, and Williams (1994) for a discussion of this issue. For purposes here, the key finding was that behavior was not affected by whether rewards were in cash or extra-credit.

2. Subjects in the 40 and 60-round experiments were paid in cash $.50 for each "experiment dollar" earned due to the large number of decision rounds.

References

Ahn, T. K, 2000, "Cooperation in the Finitely Repeated 2X2 Social Dilemma Game," working paper, Indiana University.

Andreoni, J., Miller, J., 1993. Rational cooperation in the finitely repeated prisoner's dilemma: experimental evidence. *The Economic Journal* 103, 570-585.

Bolton, G.E., Ockenfels, A., 2000. ERC: A Theory of Equity, Reciprocity, and Competition. *American Economic Review,* March, 90, no.l, 166-193.

Carpenter, J.P., 2000, "Punishing Free-Riders: The Role of Monitoring Group Size, Second-Order Free-Riding and Coordination," working paper, August.

Dickinson, D.L., 2000, "The Carrot vs. the Stick in Work Team Motivation," working paper, Department of Economics, University of Utah.

Fehr, E. and S. Gächter, 2001, "Cooperation and Punishment," *American Economic Review,* forthcoming.

Fehr, E., Schmidt, K., 1999. A Theory of Fairness, Competition, and Cooperation. *Quarterly Journal of Economics* 114,817-868.

Fisher, J., R.M. Isaac, J. Schatzberg, and J. Walker, 1995, "Heterogeneous Demand for Public Goods: Effects on the Voluntary Contributions Mechanism,", *Public Choice,* 85 (3-4), December, 249-266.

Isaac, R.M. and J. Walker, 1988, "Communication and Free Riding Behavior: The Voluntary Contribution Mechanism," *Economic Inquiry,* 26 (4), October, 585-608.

Isaac, R.M. and J. Walker, 1991, "Costly Communication: An Experiment in a Nested Public Goods Problem," *Contemporary Laboratory Research in Political Economy,* ed. Tom Palfrey, U. of Michigan Press, 269.-286.

Isaac, R.M., J. Walker, and A. Williams, 1994, "Group Size and the Voluntary Provision of Public Goods: Experimental Evidence Utilizing Large Groups," *Journal of Public Economics,* 54 (1), 1-36.

Kreps, D.M., Milgrom, P., Roberts, J., Wilson, R., 1982. "Rational cooperation in the finitely repeated prisoner's dilemma," *Journal of Economic Theory* 27, 245-252.

Laury, S., A. Williams, and J. Walker, 1999,"The Voluntary Contribution Mechanism: Provision of a Pure Public Good with Diminishing Marginal Returns," *Public Choice,* 99, 139-160.

Ostrom, E., R. Gardner, and J. Walker, 1994: *Rules, Games, and Common-Pool Resources.* Ann Arbor: University of Michigan Press.

Palfrey, T.R., Prisbrey, J.E., 1997. Anomalous behavior in public goods experiments: how much and why?

American Economic Review 87, December, 829-846.

Schmitt, P., K. Swope, and J.Walker, 2000. "Collective Action with Incomplete Commitment; Experimental Evidence," *Southern Economic Journal,* Vol. 66, No.4, April 2000, 829-854.

Sefton, M., R. Shupp, and J.Walker, 2000. "The Effect of Rewards and Sanctions in Provision of Public Goods," Indiana University Working paper.

Selten, R., M. Mitzkewitz, and G.Uhlich. 1997. "Duopoly Strategies Programmed by Experienced Players," *Econometrica,* 65 (3), May, 517-55.

Figure 1. VCM Group Allocations - Changes in Group Size and MPCR

Source: Noussair and Walker (1998)

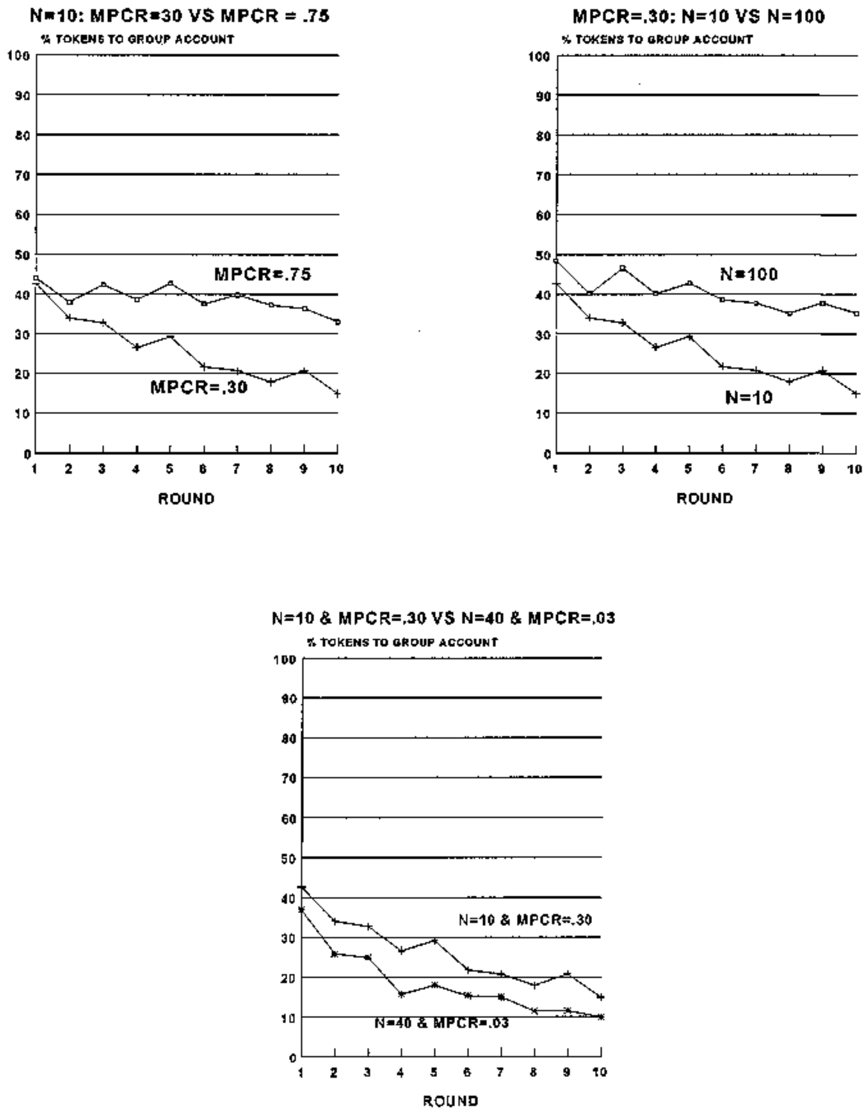

Figure 2. VCM Group Allocations: Additional Information and Longer Time Horizon (Data from Isaac, Walker, and Williams, 1994)

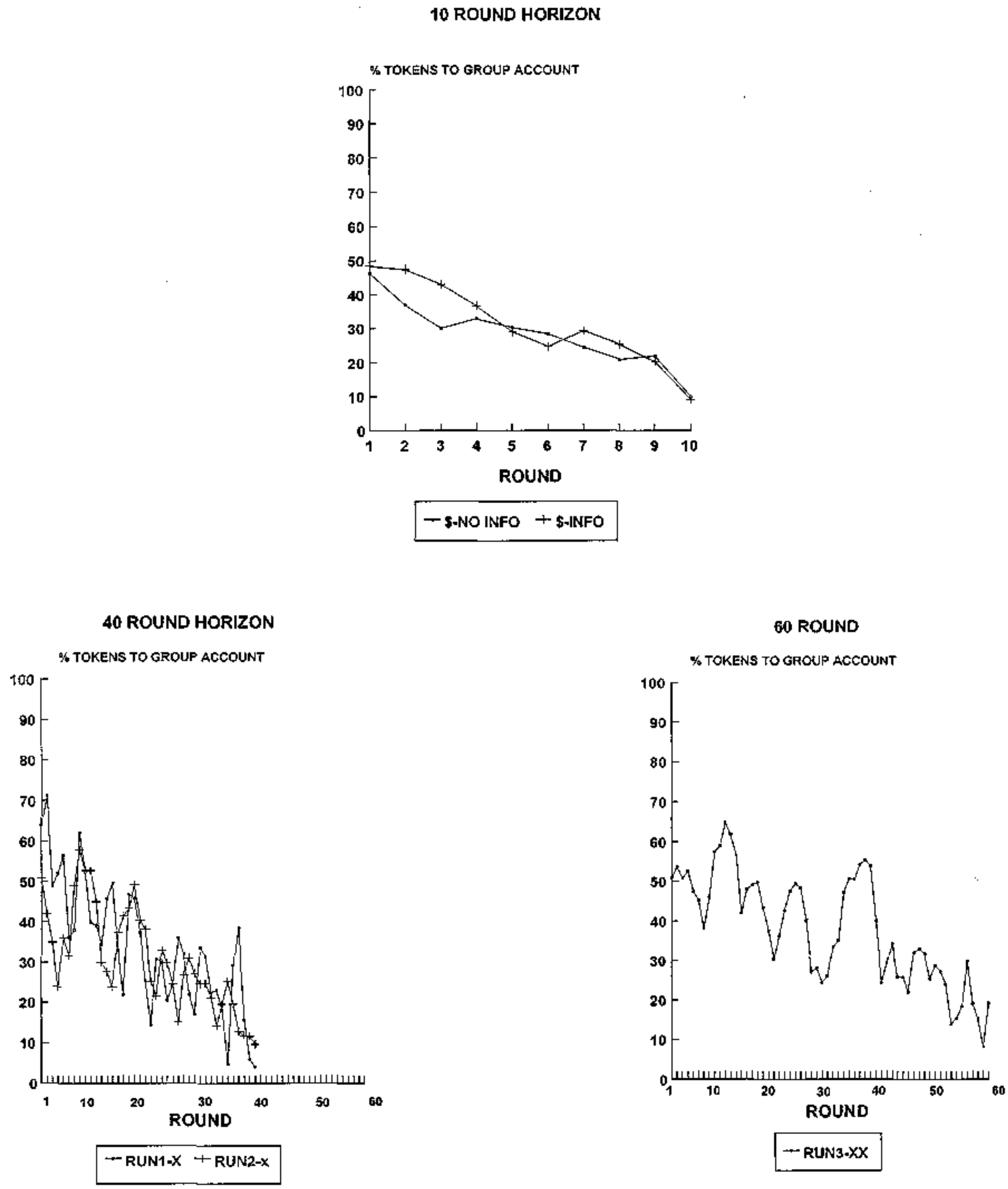

Figure 3. VCM Group Allocations: With and Without Face-to-Face Communication (Data from Isaac and Walker, and Williams, 1988)

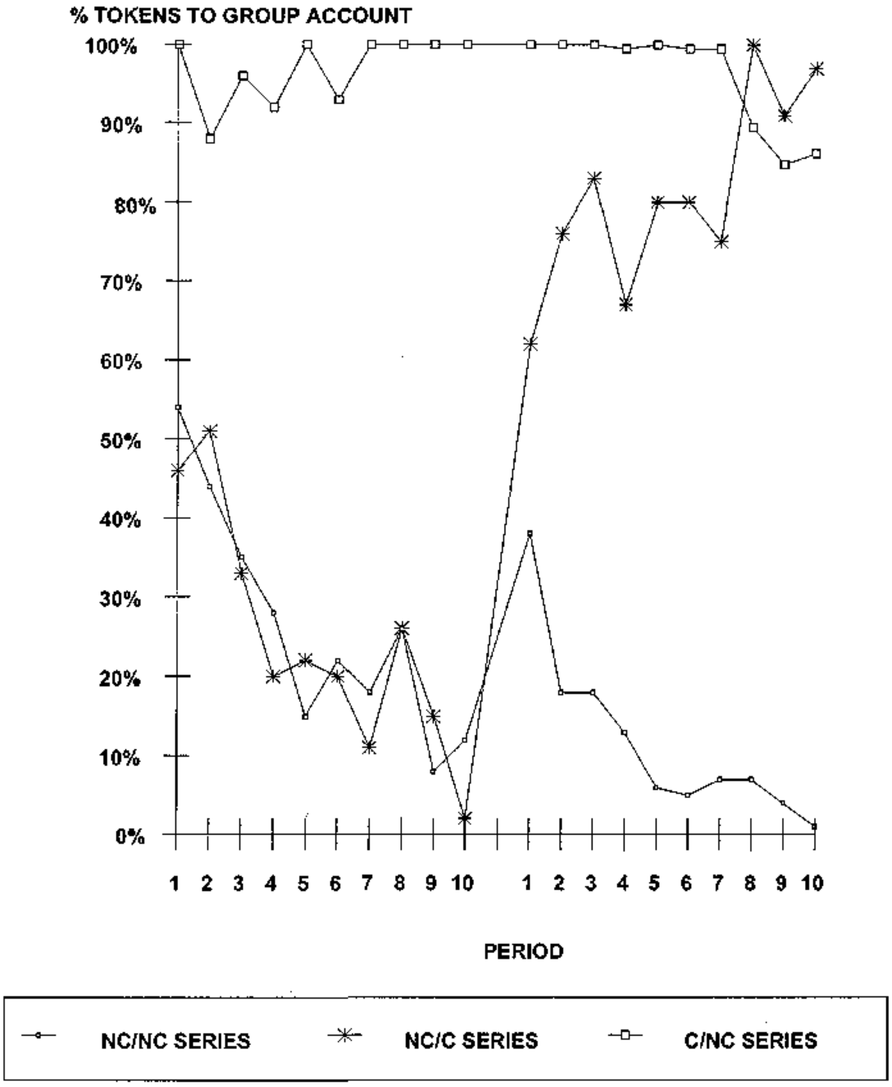

Figure 4. Tokens Used for Sanctions and/or Rewards
(Reprinted from Sefton, Shupp, Walker, 2002)

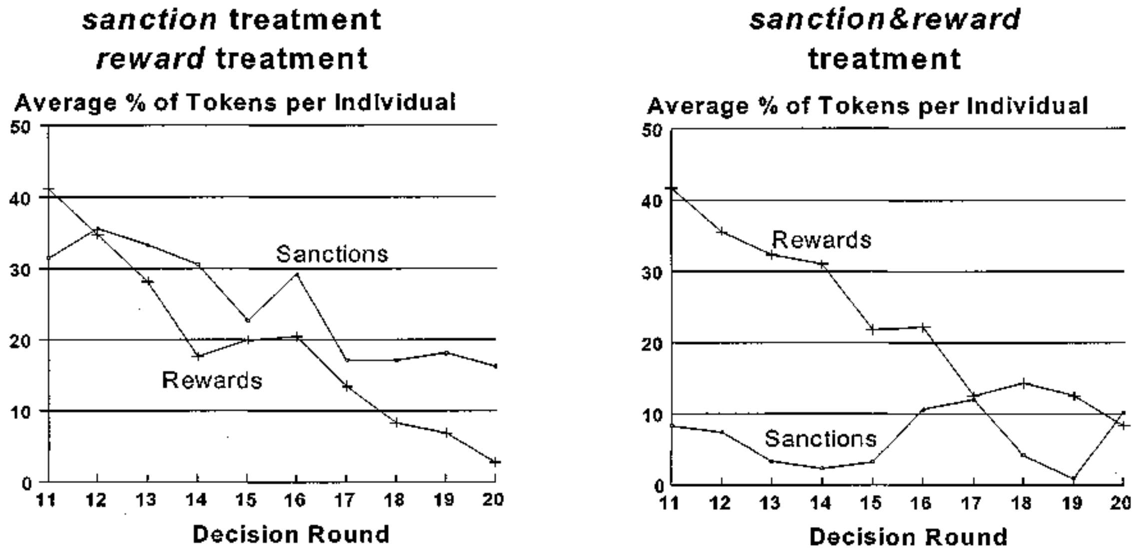

Figure 5. VCM Group Allocations
(Reprinted from Sefton, Shupp, Walker, 2002)

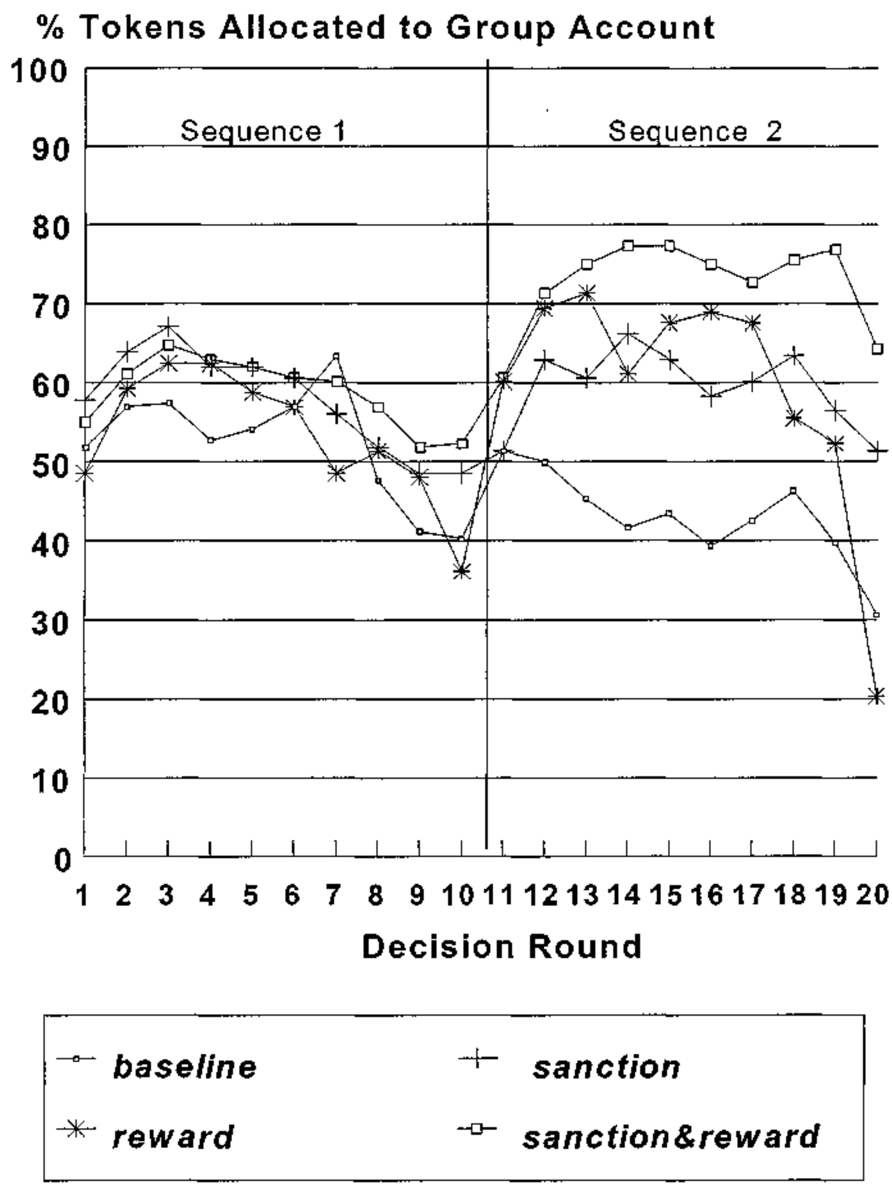

Figure 6. Efficiency: Earnings as a % of Maximum
(Reprinted from Sefton, Shupp, Walker, 2002)