Workshop Colloquium - V691

Monday, November 3, 1997

12:00-1:30 pm

Presenter: Professor Edna Loehman

Workshop in Political Theory and Policy Analysis

513 N. Park (812) 855-0441 workshop@indiana.edu

Professor Edna T. Loehman, Department of Agricultural Economics, Purdue University, will be the speaker for the Workshop Colloquium on Monday, November 3,1997. Her presentation is entitled "Testing a Coordination Process for Shared Goods: The Possibility of Successful Collective Action." An abstract of her talk is provided below.

This paper reports the design and testing of a coordination process for finding a group agreement simultaneously about cost sharing and the nature of a shared good. The process was designed to search for a cost sharing equilibrium, a particular type of Pareto optimum. The cost share equilibrium is a generalization of a Lindahl equilibrium in that it uses personalized prices to determine cost shares.

The experiment tested a two-stage game: a proposal phase based on a coordination algorithm; and a voting stage to find a unanimous agreement. No demand revelation incentives were used, but unanimity voting seemed to inhibit free-riding. Outcomes close to Pareto optimal were obtained in three rounds, even with some misrepresentation of demands. Examination of individual behavior reveals that strategic behavior is affected by institutional rules, information, and group interactions.

A copy of her paper is available by calling the above number. Colloquium sessions begin at 12 noon and adjourn promptly at 1:30 pm. You are welcome to bring your lunch. Coffee is provided free of charge and soft drinks are available. We hope you will be able to join us!

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Testing a Coordination Process for Shared Goods: The Possibility of Successful Collective Action

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Testing a Coordination Process for Shared Goods:
The Possibility of Successful Collective Action

This paper reports experimental testing of a coordination process to facilitate group decisions about shared goods. A coordination process is an algorithmic procedure (Reiter, 1995) that aims group interactions toward Pareto efficiency in resource allocation. The need for coordination has to do with the complexity of making group decisions: preferences and endowments differ, and there are multiple possible group choices with varying costs.

Shared goods occur in both social and business contexts. A shared computer system is an example within a firm. A shared neighborhood recreational facility is an example in a social context. Public television programming is an important real world case that has been studied in economic literature (Ferejohn, Forsythe, and Noll, 1979,1982).

One important group decision aspect is determining the nature of the good to be provided. For a computer system, its size and type must be determined by the sharing parties. For public television, the member stations determine the mix of programs that will be provided. For a neighborhood park, its size and quality must be determined.

Besides quantity/quality to be provided, cost allocation—how cost is to be financed among group members—is a necessary aspect of group decision-making about shared goods. Acceptability of cost sharing rules has to do with judgement of fairness associated with the distribution of benefits and costs. In a business, all divisions may not use a computer system equally. A neighborhood may have families at different life stages that would utilize a shared park differently. Not everyone has the time or inclination to watch television. Equal sharing of costs has been a predominant solution (Young, 1994; Hackett, 1993) even when benefits of a shared good are unevenly distributed. Participants may adopt a rule of equal sharing both because it seems fair, and it is a well-defined rule that covers costs.

It has been suggested that complexity may be addressed through the design of institutional rules for resource allocation (Gottinger, 1983). Foundations for institutional design methods include: Hurwicz (1973, 1987, 1994) who proposed institutional rules and design as appropriate for economic study; Reiter (1995) who suggested that coordination could be viewed algorithmically; Smith (1976, 1978, 1979, 1980, 1989, 1994) who proposed using the experimental economics laboratory to design institutions, and tested one type of coordination process for public goods; and Ostrom, Gardner, and Walker (1994) who proposed that social context and social rules can provide important behavioral incentives. Finally, our use of unanimity voting in a cost sharing context is influenced by Buchanan and Tullock (1962), who observed in Calculus of Consent that any collective decision rule other than unanimity will have coercive aspects.

Our coordination method finds group agreement through search to determine simultaneously: the good(s) to be provided, the total group budget, and its finance among group members. It is similar to a market process in that decentralized decisions are based on price-taking behavior, and preference information is private (i.e. demand revelation is limited to each participant's responses to a coordinator). A coordinator (a role which could be carried out by a computer) determines resource allocation by executing specified rules based on messages from group members. Voting is applied to proposals generated from the coordination algorithm. Unanimity voting has potential as an institutional check on free-riding, particularly in a small group, because the group may not approve a cost allocation that is too skewed.

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Design issues concern how rules are specified, in particular the policy instrument, allocation rule, information/communication, and termination rules for the process. Experimentation is used to test the interaction of institutional rules with behavior for the shared good environment. Experimental results show that group outcomes close to efficient are obtained without any other demand revelation instruments. Results also indicate that fairness aspects seem to be important in group agreements. The descriptions below explain the economic theory background, experimental design, and experimental results.

The Cost Share Policy Instrument

Besides information and decision structure associated with decentralization in mechanism design literature, here we address another design issue: the nature of the policy instrument to be implemented by a coordinating agency. The policy instrument is an allocation rule that determines resource allocation (see Appendix A for a more complete description). To be satisfactory (Hurwicz, 1973) the policy instrument should achieve Pareto efficiency via equihbrium of decentralized decisions in an abstract economy (i.e. ignoring potential strategic behavior).

More than one type of policy instrument may in theory result in Pareto efficiency, e.g. the cost share policy instrument used here is a generalization of the Lindahl equuibrium. However, not all reasonable policy instruments would be satisfactory for the shared goods situation. For example, the voluntary contribution mechanism—even without incentive problems—would not lead to a Pareto efficient solution when the quantity of the public good is a variable (Bagnoli and Lipman, 1989).

A simplified public goods economy is used here to describe the cost share policy instrument. The environment consists of a set of preferences and incomes for players and a cost function for a shared good as related to a private good. Pareto efficiency for a shared good Q is the solution of a vector optimization problem (Takayama, 1974):

$$\max_{Q,x_i} \ \Sigma \beta_i u_i(x_i, Q) \quad \text{s.t.} \quad \Sigma x_i + C(Q) \leq M$$

for private consumption for each player x_i where $C(Q)$ is the cost of the shared good relative to the private good, individual incomes are M_i which sum to M, and β_i are weights on players. Potentially, there is a Pareto optimum solution for each set of weights. Substituting for a player's weight in terms of his/her marginal utility of income, Pareto efficient outcomes satisfy the well known Samuelson condition:

$$\sum_i \frac{u_Q^i}{u_x^i} = C'(Q) .$$

(If Q is a vector, this problem is modified to have multiple conditions of this form, one for each element of the vector, and partial derivatives of the cost function form the right hand side.)

As a decentralized solution for the group resource allocation problem, the cost share equilibrium concept was proposed by Mas-Colell and Silvestre (1989, 1991). A cost share system is a set of personalized charge functions T_i such that $T_i(0)= 0$ and

$$\Sigma\, T_i(Q) = C(Q).$$

In a truthful setting, each person's proposed quantity Q_i is determined by:

$$\max_{x_i, Q_i} \; u^i(x_i, Q_i)$$
$$\text{s.t. } x_i + T_i(Q) \leq M_i.$$

Determination of a quantity generalizes price-taking behavior: rather than price, a charge function is taken as given in determining the quantity demanded for the shared good.

At a cost share equilibrium, each person makes the same quantity demand (the "common quantity") for the given charge functions. A cost share equilibrium is a feasible Q^* such that no player would prefer a different shared good level for the given charge function:

$$u_i(x_i^*, Q^*) \geq u_i(M_i - T_i(Q), Q) \text{ for all feasible } Q.$$

A linear cost share equilibrium (CSE) is a special case that uses a set of personalized prices p_i and shares s_i (Mas-Colell and Silvestre, 1991). The form of the cost share instrument is a personalized charge function:

$$T_i(Q) = s_i\, C(Q) + p_i\, Q$$

with prices that sum to zero. (For a vector of shared goods, the personalized price is a vector; there is a personalized price for each good for each player.) The resulting equilibrium is Pareto efficient because prices sum to zero.

Specifying the form of the charge function does not address how to locate a specific equilibrium in a (given) environment. That is the purpose of the coordination algorithm described below.

Design of the Coordination Game

The specification of rules for the exponential game include allocation rules, information/communication rules, and termination rules for the process. (See the Appendix B for a taxonomy of types of rules.)

Allocation Rules: The Quantity Process

To specify the personalized charge function to locate a cost share equilibrium, its parameters (cost shares and personalized prices) must be identified. Equal shares is a natural starting point for shares s_i, with personalized prices set to zero. In general, a cost share equilibrium will be associated with ex post cost shares $T_i(Q)/C(Q)$ that are not equal.

The coordination process tested here is called the "Quantity Process" because messages from group members to the coordinator concern quantity demanded for a given charge function. The message space is $\{(Q_i, T_i(Q; s_i p_i))\}$. That is, communication between the coordinator and group members is in terms of quantities and charge functions.

Procedural rules (the algorithm) for the Quantity Process are as follows:

1. Given the charge function $T_i\ (Q_i;s_i p_i)$, each person determines the individual quantity proposal Q_i.

2. The coordinator averages individual proposals Q_i to obtain the group proposal Q^*.

3. The personalized price p_i' for each member for each good is determined. The following rule, given a previous value of p_i, is used.

$$p_i' = p_i + s_i\ [MC(Q_i) - MC(Q^*)].$$

That is, if a person's Q_i proposal is greater than the group average, and marginal cost is increasing, that person's price will increase; conversely the price will decrease if the demand is smaller than the group average. (A different rule can be formulated for the decreasing marginal cost case.) Note that at an equilibrium, when each person's demand is the same, prices will be unchanging.

The resulting prices are then normalized to sum to zero, so that feasibility in terms of the group budget constraint is satisfied at any equilibrium.

The process repeats until a common $Q^*(Q_i = Q^*$ for all i) is obtained in step 1. This will be the cost share equilibrium. Steps 1-3 together with the specification of the starting point for prices and shares are the allocation rules for this process.

In comparison, the voluntary contribution mechanism uses bid messages (instead of quantity messages), and the level of the shared good is determined from the sum of the bids (rather than from the average demand for given cost shares). Also, voluntary contribution uses no formal algorithm, although experiments have repeated the procedure (Isaac and Walker, 1988, 1994a,b).

Experimental Design

The purpose of the experimental design was three-fold: 1) to test the efficiency and other properties of the Quantity Process in a game context; 2) to test the effects of heterogeneity in this context; 3) to compare the relative attractiveness of the cost share equilibrium and equal cost shares as a basis for group agreement.

Heterogeneity in reward and endowments in a voluntary bid mechanism was tested by Chan, Mestelman, Moir and Muller (1995). In contrast to Isaac and Walker (1988a), they found that heterogeneity in endowments and preferences somehow aids public good provision. However, they found that heterogeneity in both endowment and preferences reduces public good provision compared to heterogeneity in either dimension separately.

Voting and Termination Rules

In our experiment, the coordination algorithm is embedded in a voting game. The first stage consists of the coordination process described above, in which proposals for resource allocation are generated. In the second stage approval voting, the group must reach a unanimous agreement to select a group plan among the set of proposed resource allocations. The group may select any one of the proposals generated. If no unanimous agreement is found, a noncooperative outcome is the default, similar to what happens in natural groups that cannot reach agreement! Similarly, many naturally occurring group processes involve two stages with proposals and voting.

The starting point for the Quantity Process is equal cost shares. Group member quantity demand messages then result in cost sharing proposals that differ from equal shares. At a cost share equilibrium, there is a common quantity demanded by all members of the group. However, the proposal rounds end when all group members vote to end the proposal stage. That is, the proposal stage may end without agreement about a common quantity. Even if a cost share equihbrium is located, it may not be selected as the group consensus, since the cost share equilibrium will not necessarily be preferred by all players in comparison to other proposals. Since the starting point is equal shares, equal shares is also a candidate for a group solution.

This game form allows testing of the potential incentive effect of unanimity voting on free-riding. No other demand revelation instruments (such as in Groves-Ledyard, 1977, 1980, or Smith, 1978) were used in the process. Following Ostrom et al.(1994), we hypothesize that the group context itself can provide incentives for demand revelation: since all members must agree, proposing something that seems very unfair to other members may not be selected.

Similarly, Walker, Gardner, Ostrom, and Herr (1996) used a two stage voting game to allocate a common pool resource with an externality. However, they used majority voting rather than unanimity, and "tyranny of the majority" was obtained in a large number of trials.

Experimental Design and Information

The environment for this game consists of group size, endowment, reward schedules for each player, and the cost function. Group size was three members, with heterogeneity in rewards and endowments. In the game situations, either one or two players could not afford to provide the good alone. (See Appendix C for instructions.)

To induce values (Smith, 1976), players were rewarded based on a specified cost and utility function and were given endowments as income. There were three types of players in each game: A = (High Reward, Low Endowment); B= (High Reward, High Endowment); C=(Low Reward, Low Endowment). Each subject was assigned to each of the three socioeconomic types over the course of three games.

Each group participated in a practice game (no actual payoff) followed by three actual games. There were four or five groups playing simultaneously. To avoid strategic behavior based on learning about group members, following Andreoni (1988), group members were mixed randomly for the second and third real games.

There were two information treatments. In the "no information" cases, players were told in general terms that the group composition is heterogenous in terms of reward and endowment, but no emphasis or specific information about the nature of other players was given. In the "information" treatment, players were given specific information about their own type and the types of other players for each game.

Information was presented in the form of charge, reward, and net payoff schedules for potential levels of the public good Q; there were ten levels ranging from 0 to 9. After seeing the information screen giving costs and returns by level of public good, subjects responded with messages about desired quantities. There was no direct communication among group members. Message exchange was only between the coordinator and each subject. Summaries of quantity proposals and shares of cost for all group members by round were available as public information on history and voting screens.

No incentive for demand revelation was used. To the contrary, incentives for revealing a low demand were present, since subjects were told that their share of cost would depend on their public good demand proposal relative to others' proposals: starting from equal shares, those with demands less than the average would receive less than an equal share in subsequent rounds, while greater than average demand would result in greater than equal shares. A subsidy (negative charges) can even occur for players that propose quantities less than the group average.

The game also includes a noncooperative alternative. For the noncooperative alternative, the subject reward is the same as in group participation, but the full cost must be paid (not shared), so that net returns for any quantity level are less than in the group. The same information format— in terms of cost, reward, and net payoff schedules— is used for both group participation and the individual noncooperative situation. In both group and noncooperative cases, the subject is asked to select a quantity level. Presentation of the noncooperative case is used to make sure that optimization in the schedule format is clear to the subject. The best individual plan is the noncooperative alternative. As a reminder on game screens, this noncooperative outcome is displayed for comparison to all group resource allocation proposals.

The initial charge schedule has equal shares s_i and zero prices. After each subject makes a quality proposal, a charge schedule with new proposed shares of cost is displayed, with corresponding new values for net payoffs. After making a quantity proposal, each group member also votes whether or not to stop the proposal process, similar to procedures in a naturally occurring group. Unanimity was required to stop the proposal process and go on to the approval phase. If the group does not agree to stop the proposals within a certain number of rounds, then the proposal process can have a randomized end (to simulate discussion breakdown in a natural process). In the trials reported below, subjects were told that the proposal phase would end with probability of 0.5 after five proposal rounds.

For the Approval Phase, each subject is shown a screen with summary information for all the generated proposals and asked to vote "yes" or "no" for each proposal. In order for a proposal to be selected, all members must approve it. Multiple "yes" votes were permissible, and with ties, the computer selected the one with minimum variance in quantity. In the case of no agreement, all group members would receive the noncooperative allocation.

Information regarding players' voting preferences was provided. Subjects were first asked to rank their top three proposals. The ranking for each member was then displayed as public information for approval voting purposes. The idea is similar to Hare voting: plans that are nobody's favorites may be ignored. On the other hand providing this information could create potential disagreement, e.g. if a person refuses to approve a proposal that is someone else's top choice, but not their own top choice. Given ranking information, three chances at approval voting were given.

The costs and payoffs were determined as follows. The cost function is of the form: $C(Q) = 100 + 10\,Q - 5\,Q^2 + 5\,Q^3$. Each of three players has a quasi-linear utility function of the form: $u_i(x_i, Q) = x_i + \gamma_i \log(1 + Q)$. For this type of utility, there is a theoretical efficient Q that is independent of the distribution of income (Bergstrom and Comes, 1983); the efficient solution maximizes the sum of utilities. Each of the three games was of this form but had different parameters determining a different efficient Q.

Experimental cost for each session was about $300 based on an average of about $15 per subject plus a $5 show up fee. Session took about two hours each for a practice game and three real games.

Results

Interestingly, there was no significant effect of the heterogeneity information treatments except on individual behavior (free-riding or overbidding). Relatively similar group efficiencies were obtained regardless of the heterogeneity information treatment. Significance of treatments was tested by one-sided t-tests (see tables).

Group Results

Table 1 shows the efficiency resulting from the two heterogeneity information treatments. The efficiency measure is the ratio of the group quantity selected to the theoretical optimum. In marked contrast to voluntary contribution results that decay with repetition (Isaac and Walker, 1988a), the group decision efficiency increased to over 80% on the third game. The increase in efficiency of the third round compared to the second round is statistically significant. There is no significant difference by information treatment.

Table 2 shows the number of proposal rounds (iterations of the algorithm). This measure can be associated with transactions costs in a natural group setting: a coordination process would not be satisfactory if it required a large number of iterations to reach a good outcome. Each game equilibrium could have been found theoretically in three proposal rounds, if proposals were truthful, whereas strategic behavior increases the number of rounds to find a cost share equilibrium. The average number of rounds for each game is not statistically different for the two information treatments. Pooling the information treatments, the number of rounds for the second and third game is significantly greater than for the first game. Evidently, players began to explore more strategies for how to play the game after the first round.

Table 3 shows the proportion of "successes" in finding the cost share equilibrium (CSE). Overall, a CSE (having the same quantity demanded by each group member) was found in 46% of the games. The greatest success rate is on the last game. There is evidently a learning process: the percent of successes for the second game was significantly greater than for the first game, while the third game had about the same success rate as the second game. There is no significant difference due to information treatments.

Table 4 examines the approval rate for the cost share equilibrium. Overall, the approval rate for the cost share equilibrium is 21%, less than half of the events in which the cost share equilibrium was found! The second game has the largest approval rate for the cost share equilibrium. The lowest approval rate is on the first game. Game sequence effects are significant: the second game has a higher approval rate than the first game, while the third game has a lower approval rate than the second game. Group members may learn after the first game that it is desirable for agreement to look for proposals with smaller variance among group member proposals. However, on the last game, strategic behavior and fairness concerns may cause a movement away from approving the CSE. There is no statistical difference due to the information treatment.

Conditional probabilities in Table 5 are CSE approvals relative to finding the CSE. Again, the highest rate is for the second game, with a lower rate on the third game; the differences are statistically significant. For the second game the probability of approving the CSE given that it is found is 73%! A lower rate is found for the information treatment; however information does not have a significant effect.

Table 6 shows the approval rate for the equal shares solution. Overall the approval rate is 31%, considerably higher than for the cost share equilibrium. Thus, even when there is heterogeneity, equal shares is a robust sharing rule. Again, there are significant game effects between the first and second games, and between the second and third games. The highest approval rate is found for the first game, which also has the lowest approval rate for the cost share equilibrium. The lowest approval rate is for the second game, which also has the highest approval rate for the cost share equilibrium. Compared to the conditional probabilities, only the first game has a higher approval rate for equal shares. Again, the heterogeneity information does not cause a significant difference in approval rates.

About a third of the unanimous agreements were neither the equal shares solution nor the cost share equilibrium. Failure to reach a group agreement occurred in only 12/69 (17.3%) games for the "no information" and for 9/75 (12%) of the "information" games, for an average of 14.5% (this difference is not statistically significant). Many of the cases in which there was no agreement involved a subsidy for one of the players because of free-riding.

Individual Behavior Results

There has been relatively little testing of individual behavior in economic games (one example is Weimann, 1994). Our experimental design allowed examination of strategic behavior by type of player and by heterogeneity information treatment.

Free-riding was only examined on the first round of each game. Comparing the theoretical quantity proposal with the actual proposal, a lower proposal than the theoretical optimum was designated as free-riding. (Such lower proposals by a player resulted in that player obtaining a relative subsidy in subsequent rounds.) Surprisingly, there are also players ('over bidders') who proposed a quantity greater than the theoretical optimal proposal, thus incurring a relatively larger cost share. Perhaps this overbidding behavior was to signal others. In any case, because quantity is determined by averaging proposals, it offset the effects of free-riders. Free-riding and overbidding are significantiy affected by the type of player and by the information treatment.

Table 7 shows that free-riders were about equally distributed over the three games, with an average of about 25% of the players free-riding. There is no significant difference between information treatments in terms of percent of free-riders. However, there is a game sequence effect: the percent of free-riders dropped significantly on the second game and increased significantly on the third game. Evidently, free-riders who were punished on the first game by inferior group solutions behaved better on the second game (see Tables 11a,b).

Information effects are significant for both the high reward, low endowment and low endowment, low reward players (Table 9). Free-riding occurs most frequently for the "information" case for the low endowment, low reward players. Evidently, when informed about their relative position, these players may feel that they are disadvantaged and thus have the right to under-reveal. Free-riding is least for the informed high reward, low endowment players; they had the most to lose from no agreement!

Table 8 shows that, overall overbidders are about the same proportion (26%) of the players as free-riders. However, in contrast to Table 8, overbidding increases (statistically significant between both pairs) as the sequence of games proceeds. Overbidding is similar over all player types in the "no information" treatment (Table 10). Information causes a significant effect for both the high reward/high endowment and low reward/low endowment players. Perhaps not surprisingly, the most overbidding is by high reward, high endowment players, whereas the least overbidding is by low reward, low endowment players.

To indicate game learning effects on individual behavior, Tables 1 la,b trace the history by player for two sessions, one for each information treatment. Only in one case did a given player exhibit free-riding over all three games. In one case, a player was a free-rider for two games and then switched to overbidding. In six out of seven free-riding cases for the first game, players who attempted free-riding were punished either by the group reaching no agreement or by an inferior group agreement; subsequently these players did not free-ride again.

Research Issues

Some research topics suggested by this research are described below, for future research.

Will a cost share equilibrium be selected more frequently when group members have a continuing relationship through several games? Does approval of the CSE depend on the nature of the good?

For naturally occurring processes, a situation with all agreeing on the same shared good may be of more interest when group members have a continuing relationship (in contrast to a laboratory situation when everything is transformed to monetary terms and there is no continuing relationship). Instead of mixing group members every game, experimental game series could keep the same group composition to see if the common quantity solution becomes more attractive.

Also, the nature of the good could be alterred (e.g. a group meal in a restaurant) to see the affect on agreement.

What are the effects of group size, as related to voting rules, on resource allocation?

For a larger group size (e.g. a group of size five), it may be more difficult to come to a unanimous agreement with a unanimity voting rule. A larger group size may also affect free-riding (as suggested by Olson, 1965).

How does the type of voting rule and exit costs for group choice affect the outcome?

A majority voting rule is more definitive than a unanimity rule in that a decision can be found even in a large group. However, in a small group with low exit costs, a majority decision could not be imposed on a minority. Depending on the noncooperative outcome, a disagreeing minority would defect, and the larger group would fall apart.

How does the type of coordination algorithm affect the outcome?

The voluntary contribution mechanism represents a different computational algorithm than the Quantity Process tested here. Although results with voluntary contribution may be improved through imbedding in a unanimity voting game, the theoretical efficient outcome may still not be attained without direct communication, because of the nature of the algorithm. Other coordination algorithms are also possible (see Loehman and Rassenti, 1995).

Conclusions

Smith (1989) and Hurwicz (1987) proposed design of institutions as a social engineering activity for economists. The Quantity Process coupled with unanimity voting is an example of social engineering that combines aspects of economics with numerical analysis and voting.

As Smith and others have demonstrated in many applications, experimental testing can be useful to further develop institutional rules. In this context, Schotter's (1995) criteria for naturally occurring mechanisms can be adopted to evaluate the success of engineered institutions: understandability, fairness, robustness for a variety of environments, and individual rationality.

By these criteria, our experimental tests showed the Quantity Process coupled with unanimity voting to be successful! For a complex environment, the coordination process—even with some free-riding—produced a group agreement in a few rounds that was close to efficient. Similar efficiencies were obtained over information treatments, and there was improvement as players learned about the coordination process over the course of the games. Strategic behavior also increased over the games, but the second stage unanimity rule appeared to limit free-riding while the quantity averaging allocation rule allowed overbidding to counteract free-riding. Fairness considerations were included by allowing the heterogeneous players to select among the proposals including equal cost sharing as an option.

The cost share equilibrium was located by groups in nearly half of the games but was unanimously approved in only about 20% of the games, producing an average conditional success rate of less than 50%. Equal sharing of costs was approved in about 1/3 of the games. Thus, in spite of heterogeneity, equal shares is an important focal point for group agreements about shared goods.

Future research will continue investigation of the interaction between institutions and individual behavior in a group shared goods environment. The coordination methods tested in this research may be most relevant for relatively small groups. The preferred group decision method or process may be largely determined by group size (here relatively small). In a larger heterogeneous group, it may be more difficult to arrive at simultaneous decisions about quantity/quality and finance, and unanimity may not be achievable. Environmental factors—such as group size, the nature of the good(s) to be shared, heterogeneity of group membership, and the nature of the underlying cost situation—will undoubtably affect the success of institutional rules for a group decision process.

Appendix A: Formal Description of Allocation Rules, Adjustment Mechanisms, and Coordination

The following description of an allocation rule extends the definition by Calsamiglia (1977, 1987) for institutional design purposes. An allocation rule (h) is a mapping from messages by players (m_i^t) to resource allocation, given the environment (e) and other institutional rules (I,P):

$$a^t = h(m_1^t, m_2^t, \ldots, m_n^t; e, I, P).$$

As described by Hurwicz (1973, 1979, 1994), message selection by a player is based on preference over outcomes given the strategies available to the player and information about messages of other players. Strategies are limited by the environment and the rules (h,I,P). The resulting behavior rule b_i for each player is described by:

$$m_i^{t+1} = b_i(m_1^t, m_2^t, \ldots, m_n^t; e, h, I, P).$$

Composing the allocation rule h and the behavior rules b gives a mapping from a point in the message space to another point in the message space. An adjustment process is an iterative composition of these two types of rules: given a message vector and resulting allocation, if improvement in utility is possible, each player will select a new message from the strategy set.

A Nash equilibrium N(e; h,I,P) is a stationary point for the adjustment process, when no player has an incentive to change his/her message from the equilibrium message given the messages of other players.

In mechanism design, the rules (h, I, P) are treated as variables. Alternative rule designs can be evaluated in terms of the desirability of resulting resource allocations (Hurwicz, 1994). The goal is to design rules so that Nash equilibrium and Pareto optimality coincide. For example, Groves and Ledyard (1977, 1980) designed an instrument to address this correspondence for shared goods with demand revelation problems.

A coordination process is a special type of adjustment process with the goal of achieving Pareto optimality for a group decision problem. As defined by Reiter (1994), coordination has an algorithmic structure.

The environment here includes group size, the nature of cost, and the nature of individuals in the group in terms of preference and income. The institutional rules include the policy instrument (P) and rules (I) such as the type of message and the nature of the algorithm. Termination rules are another type of rules, here of the voting type.

Appendix B: Important Game Design Features

Information. Information has been shown to have an important influence on game outcomes (Rapoport,1988; Isaac and Walker, 1994)). Message order can affect equilibrium Varian (1994).

Communication. Communication is information about future planned strategies. It is generally acknowledged that communication improves group outcomes (for example, Ostrom et al., 1994).

Noncooperative Alternative. The experiments of Isaac and Walker (1994) and Chan et al. (1995) for voluntary contribution suggest that presence of a noncooperative alternative can affect behavior in a cooperative setting. The noncooperative case may serve as a reference point for the bidding process.

Heterogeneity. The effect of income distribution of voluntary contribution has been studied theoretically by Bergstrom, Blum, and Varian (1986) and experimentally by Chan et al. (1995). They found that regressive income distribution increases voluntary provision of the public good. Also, relatively rich individuals tend to under contribute!

Termination/ Voting Rules. One type of termination rule is the Nash equilibrium, when there are unchanging messages. A related rule is stability in the differential equation sense as discussed by Jordan (1987).

Voting over proposals is a familiar group decision rule that has been applied for budgeting problems. There are many types of voting rules (Nurmi, 1987). While voting alone may not produce efficient social outcomes (Frohlich and Oppenheimer, 1978), approval voting can have important incentive effects as shown by the work of Walker et al., 1996.

Learning. Andreoni (1988) has discussed the problem of players learning about the strategies of other players in a public good context. He controlled this by randomizing players over groups. On the other hand in a social context, continuing collaboration could change the nature of strategies.

Appendix C: Game Instructions (full screens available from the authors)

You are a member of a three person group that will try to reach agreement about purchase of a shared commodity. Agreement entails determining the plan to be purchased by the group and how its cost will be allocated among members of the group.

You and other members of your group will receive rewards at the end of the process depending on the decisions made by each group member.

Press PgDn to continue

Endowment, Reward, Cost, and Payoff

You will receive an initial endowment that you can use for purchasing the plan. Depending on the plan selected by the group, you will receive a reward. You will also be asked to share the group cost for the chosen plan. Your net reward will be determined by your benefit for the chosen plan minus your share of the cost plus your endowment.

If you do not agree to the group solution, your alternative is to purchase the commodity as an individual and pay the full cost.

You will be participating in several independent group decision processes. Your endowment, reward, cost, and group members will differ in each group decision process.

Press PgDn to continue, PgUp to review

Description of Proposal Phase

1) Make Plan Proposals:

Each round, you will propose your quantity plan for the group. Your choice should be based on your benefit and share of cost for each plan.

The group quantity plan for each round will be the average of members' quantity plan proposals.

Each round, your share of cost for each plan will be determined for the next round by the computer based on your plan proposals.

Initially, shares of cost are equal for each group member. On subsequent rounds, if you propose a quantity plan larger than the group plan, your cost share will be greater than an equal share. Conversely, if you propose a quantity plan less than the group plan, your cost share will be less than an equal share.

2) Vote to continue or stop the proposal process:

If the Proposal Process does not end within a set number of unrestricted rounds, it will end unannounced on some succeeding round.

NOTE: Numbers on tables are in computer PESOS

Press PgDn to continue, PgUp to review

Decision Process

The group decision process will have two phases:

1) a Proposal Phase

Each round of the Proposal Phase produces a group proposal consisting of a plan and the share of cost each member would pay.

2) an Approval Phase

Among proposals generated during the Proposal Phase, unanimous agreement for one proposal must be obtained during the Approval Phase. If your group does not find an agreement, your payoff will be based on your best individual plan.

Press PgDn to continue, PgUp to review

Description of Approval Phase

1) Rank plans from proposal rounds

2) Vote to approve or disapprove plans from proposal rounds

During the Approval Phase, you will compare group proposals generated during the Proposal Phase to your best individual plan.

All group members must approve a proposal for it to be selected as the group outcome.

If your group does not reach agreement within a set number of trails, your payoff will be based on your best individual plan.

Press PgDn to continue, PgUp to review

Information

The identity of group members will never be revealed. Group members will not be given information about each others' endowments and rewards.

The members of your group will all have different endowments and different rewards.

Press PgDn to continue, PgUp to review

Your Individual Plan:

Individual Net Reward = Benefit - Cost + Endowment

Plan	Total Cost	Benefit	Individual Net Reward
0	0	0	200
1	104	47	143
2	110	80	170
3	121	105	184
4	140	126	186
5	172	144	172
6	220*	159	139
7	288*	173	85
8	380*	185	5
9	499*	196	-103

*you cannot afford this plan with your endowment.

Your best individual plan will determine your net reward if no group agreement occurs.

Please type your best individual plan and press ENTER: 0

Best Individual Payoff: 200

Propose a Plan for Round 1

Net Reward = Benefit - Cost Share + Endowment

Plan	Your Share	/	Total Cost	Your Benefit In Group	Your Net Reward In Group
0	0	/	0	0	200
1	34	/	104	47	212
2	36	/	110	80	243
3	40	/	121	105	265
4	46	/	140	126	279
5	57	/	172	144	287
6	73	/	220	159	286
7	96	/	288	173	277
8	126	/	300	185	258
9	166	/	499	196	230

Type your preferred Group Plan and press ENTER: 5

Best Individual Payoff: 200

Approval Phase: Approval Voting Trial #3

Round	Group Plan	Member Proposals You	Member Proposals Others		Percent Cost Shares You	Percent Cost Shares Others		Your Net Reward In Group	Member Rankings You	Member Rankings Others		Approval Votes You	Approval Votes Others	
1	5	5	7	5	33	33	33	287	2	1	2	No	Yes	No
2	6	6	6	6	21	57	21	313	1	2	1	Yes	Yes	Yes

There was an unanimous agreement on Round 2.
You will receive a net reward of: 313 pesos = $ 9.48.

Press the SPACE BAR to continue.

Table 1. Efficiency Ratio

	Game		
	I	II	III
Efficient Q	**7**	**4**	**8**
No Info	0.76	0.71	0.83
Info	0.77	0.71	0.83
Overall	0.77	0.71^{G*}	0.83

Table 2. Proposal Rounds

	Game		
	I	II	III
Truthful	**3**	**3**	**3**
No Info	3.61	5.00	4.43
Info	3.60	4.56	5.12
Overall	3.60^{G**}	4.79	4.79

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 3. Cost Share Equilibrium Found

	Game			Overall
	I	II	III	
No Info:				
Number	8	11	15	34
Games	23	23	23	69
Percent	0.35	0.48	0.65	0.49
Info:				
Number	6	15	12	33
Games	25	25	25	75
Percent	0.24	0.60	0.48	0.44
Overall:				
Number	14	26	27	67
Games	48	48	48	144
Percent	$.29^{G**}$	.54	.56	0.46

Table 4. Cost Share Equilibrium Approved

	Game			Overall
	I	II	III	
No Info:				
Number	3	8	5	16
Games	23	23	23	69
Percent	0.13	0.35	0.22	0.23
Info:				
Number	2	7	5	14
Games	25	25	25	75
Percent	0.08	0.28	0.20	0.19
Overall:				
Number	5	15	10	30
Games	48	48	48	144
Percent	$.10^{G**}$	$.31^{G**}$	.20	0.21

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 5. Conditional Probability of Cost Share Acceptance

	Game I	Game II	Game III	Overall
No Info:				
Number	3	8	5	16
Games	23	23	23	69
Percent	0.37	0.73	0.33	0.47
Info:				
Number	2	7	5	14
Games	25	25	25	75
Percent	0.33	0.47	0.42	0.43
Overall:				
Number	5	15	10	30
Games	48	48	48	144
Percent	$.36^{G**}$	$.58^{G**}$	.37	0.45

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 6. Equal Shares Approved

	Game I	Game II	Game III	Overall
No Info:				
Number	13	2	9	24
Games	23	23	23	69
Percent	0.56	0.09	0.39	0.35
Info:				
Number	11	5	5	21
Games	25	25	25	75
Percent	0.44	0.20	0.20	0.28
Overall:				
Number	24	7	14	45
Games	48	48	48	144
Percent	$.50^{G**}$	$.14^{G**}$	.29	0.31

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 7. Free-riders by Game

	Game I	Game II	Game III	Overall
No Info:				
Number	18	15	17	50
Games	69	69	69	207
Percent	0.26	0.22	0.25	0.24
Info:				
Number	20	17	23	60
Games	75	75	75	225
Percent	0.27	0.23	0.31	0.27
Overall:				
Number	38	32	40	110
Games	144	144	144	432
Percent	.26^{G**}	.22^{G**}	.28	0.25

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 8. Overbidders by Game

	Game I	Game II	Game III	Overall
No Info:				
Number	5	19	26	50
Games	69	69	69	207
Percent	0.07	0.27	0.38	0.24
Info:				
Number	7	24	31	62
Games	75	75	75	225
Percent	0.09	0.32	0.41	0.28
Overall:				
Number	12	43	57	112
Games	144	144	144	432
Percent	.08^{G**}	.30^{G**}	.39	0.26

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 9. Free-riders by Type

	Type A	Type B	Type C	Overall
No Info:				
Number	18	20	12	50
Games	69	69	69	207
Percent	0.26	0.29	0.17	0.24
Info:				
Number	10	15	35	60
Games	75	75	75	225
Percent	0.13^{I*}	0.20	0.47^{I**}	0.26
Overall:				
Number	28	35	.47	110
Games	144	144	.47	432
Percent	$.22^{G**}$	$.28^{G**}$	$.33^{G**}$	0.25

A=High Reward, Low Endowment
B=High Reward, High Endowment
C-Low Reward, Low Endowment

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 10. Overbidders by Type

	Type A	Type B	Type C	Overall
No Info:				
Number	19	15	16	50
Games	69	69	69	207
Percent	0.27	0.22	0.23	0.24
Info:				
Number	21	36	5	62
Games	75	75	75	225
Percent	0.28	0.48^{I**}	0.07^{I**}	0.28
Overall:				
Number	40	51	21	112
Games	144	144	144	432
Percent	$.28^{G**}$	$.35^{G**}$	$.14^{G**}$	0.26

A=High Reward, Low Endowment
B=High Reward, High Endowment
C-Low Reward, Low Endowment

I - Information Effect
G - Game Effect
* - 95% t - test
** - 99% t - test

Table 11a. Patterns of Individual Strategic Behavior
No Information about Heterogeneity
(August, 1996)

Game	I	II	III
Player 1	free ride (punished)	no	no
2	no	no	over bid
3	no	no	free ride
4	free ride (punished, no agreement)	no	no
5	no	over bid (punished)	no
6	no	free ride (punished)	no
7	no	no	no
8	no	no	free ride (punished)
9	no	no	no
10	no	no	no
11	no	no	over bid
12	no	no	no
13	no	no	no
14	free ride (punished)	no	no
15	no	no	no

Table 11b. Patterns of Individual Strategic Behavior
Information about Heterogeneity
(August 1996)

Game	I	II	III
Player 1	no	no	free ride
2	no	no	overbid
3	no	no	no
4	no	no	no
5	no	no	free ride
6	free ride (punished)	no	free ride
7	no	over bid	no
8	free ride (very punished)	free ride (punished)	over bid
9	free ride	no	no
10	no	over bid	free ride
11	over bid	over bid	no
12	no	no	free ride
13	no	no	free ride
14	no	no	over bid
15	free ride	free ride (slightly punished)	free ride

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