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Voluntary Provision of Public Goods: The Multiple Unit Case

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Voluntary Provision of Public Goods: The Multiple Unit Case[1]

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1. Introduction

Economists have long held the belief that public goods will be undersupplied when funded through voluntary contributions. To many, this suggested that the government's power to command payments through the tax system was needed to provide such goods. More recently, several incentive-compatible mechanisms have been proposed as provision schemes (see Groves and Ledyard [1976], Tideman and Tullock [1977], and Smith [1980] for examples). Since these schemes share a common trait - they are quite complex to implement - they are generally viewed as an alternative to the tax system for the government to directly provide public goods.

Among the simpler mechanisms that have been studied are voluntary contribution games. Robyn Dawes and several of his colleagues have explored contribution games in a setting involving a binary decision, to contribute a fixed amount or not, by the members of the group. Palfrey and Rosenthal [1984] analyzed one

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such game and found that it is capable of generating both efficient and inefficient outcomes.

Recently, Bagnoli and Lipman [1989] have investigated two contribution games in which the individuals decide the level of their own contributions. In the first, the society must decide whether or not to provide a public good. In the second, not only must they decide whether or not to provide the public good but also how much to provide. Bagnoli and Lipman showed that their first contribution game fully implemented the core in undominated perfect equilibrium[2] while the second game fully implemented the core in successively undominated strictly perfect equilibria.[3] Clearly, the more interesting version of Bagnoli and Lipman's contribution games is the one in which the level of provision must also be determined and this is the version we address here.

Laboratory experiments provide a useful device for testing the behavioral requirements behind mechanism design. In the case of Bagnoli and Lipman's work, the desirability of running experiments follows from two behavioral aspects of their

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[2] This means that the set of core outcomes concides with the set of undominated perfect equilibrium outcomes. The latter are the trembling hand perfect Nash equilibrium outcomes in the game after the removal of all dominated strategies.

[3] The details are presented in Bagnoli and Lipman. Briefly, successively undominated means one strips out all of the dominated strategies, checks to see if this process has created more dominated strategies and continues until all of the remaining strategies are undominated. One then seeks the strictly trembling hand perfect Nash equilibria to the reduced game. The difference between strictly trembling hand perfect and trembling hand perfect is that, for the latter, the strategies must be robust to some set of small trembles while for the former, the strategies must be robust to all sets of small trembles.

mechanism. First, they employed refinements of the Nash Equilibrium to implement the core and so one might wonder whether the refinements are representative of actual behavior. Second, even after employing a refinement, there are multiple equilibria and so one might also wonder whether or not the players can focus on one of them. For the simple problem of whether or not to provide the public good, Bagnoli and Lipman's analysis is supported by the experimental results of Bagnoli and McKee [1989].

In this paper we report on some experiments which were designed to evaluate Bagnoli and Lipman's predictions in the multiple unit collective good setting and to address the broader question of the behavioral robustness of some refinements to Nash equilibrium.

From our results it appears that the refinement employed is not an adequate representation of behavior and that individuals have much more difficulty focussing on an equilibrium in the multiple units setting than they did in the single units setting. This is not surprising since the multiple unit game is considerably more complex, admits many more equilibrium strategies, and the refinement necessary to implement the core is much stronger than in the single unit setting. Given the additional complexity of the game and the more stringent refinement required to implement the core, our results are much more positive than we had expected. That is, we do find that the subjects are able to achieve the predicted equilibrium with some degree of regularity. However, the results are such that one would not wish to place much reliance on the proposed mechanism to provide public goods.

2. Theoretical Foundations[4]

The basic structure of a contribution game is relatively simple. Contributions to the provision of a public good are solicited from the agents in the economy. The cost of the good, the initial wealth of all agents, and the valuations for the public good of all agents are common knowledge. If the contributions sum to at least the cost of the good it is provided otherwise all contributions are returned.

Now consider an economy with I agents indexed i = 1, 2, ..., I. Each agent has a quasi-linear utility function $u = u(d) + w$ where w is wealth and d is an element in the decision set $D = \{0, 1, ..., M\}$ where d is interpreted as how much of the public good to provide and the cost of production are C(d) with $C(d) < C(d+1)$.

There are many ways one could structure the contribution game for this multiple unit case. For example, one might suppose that the agents choose contributions and the amount provided is the most that can be given these contributions. One must also specify some rule, such as the return of contributions, to cover the case where the contributions are insufficient to cover the cost of the first unit. This game does not implement the core.[5]

Instead, Bagnoli and Lipman consider a sequential structure of the following type. In the first round, the agents begin by contributing some non-negative amount. If contributions are less

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[4] In this section we provide the barest outline of the game investigated by Bagnoli and Lipman. The reader is referred to their paper for the full details.

[5] See Bagnoli and Lipman for an example that shows why this conclusion holds.

than c(1) then they are returned and no units of the public good are provided. If the contributions sum to exactly c(k) then k units are provided and the next round of contributions, with k as the new basis, begins. The process stops when the contributions in given round do not sum to the cost of an additional unit of the public good. The most difficult part of the game to specify is what happens if contributions fall strictly between c(k) and c(k+1) for some k greater than 1. As Bagnoli and Lipman note, such a situation is "falling short" in one sense and "having enough" in the other and so it is unclear what the appropriate incentives should be. They assume that the excess over c(k) is refunded in proportion to the actual contributions and then proceed in the analysis as if exactly c(k) had been contributed.

While it is clear that the multiple unit contribution game is similar to the single unit game, one must keep in mind that there is a crucial difference. In the latter, the citizens need only decide whether or not to provide an exogenously fixed level of the public good while in the former, they must decide how much, if any, to provide. The problem of obtaining the efficient outcome is much more difficult and requires a very strong refinement notion, successively undominated strictly perfect equilibria. The use of such a strong refinement immediately raises the question of its behavioral realism. Further, since equilibrium is not unique, whether the agents can focus is another open question. Finally, the additional complexity of the game raises questions about its ability to predict actual behavior.

3. Experimental Implementation and Design

In the single units case reported in Bagnoli and McKee subjects posted contributions to the provision of one unit of the public good. These sessions were conducted in a classroom setting since the amount of information to be transmitted to the subjects during the session was quite limited. Essentially the subjects had to be informed only of the total contribution of their group and whether the good was provided. The multiple unit setting is far more complicated and necessitated the use of a computerized facility.

In setting up the laboratory environment for the multiple units setting we adopted a simplifying procedure to make the task clearer the subjects. In our sessions we chose to implement this sequential game procedure by setting the step size to one unit for each decision round. The subjects were asked to post their contributions for the first unit. If it was provided they went on to the second and so on for as long as the sum of the contributions met or exceeded the cost. For the stage at which the contributions failed to cover the cost the contributions were returned to the subjects. Thus, the experimental setting strictly repeats the single unit game over a sequence. As Bagnoli and Lipman showed, in proving that every core outcome is achieved by some equilibrium, one such equilibrium has a succession of rounds with one additional unit purchased at each round and with contributions adding to exactly the marginal cost.

The subjects were provided with the information prescribed by the theory. That is, they were told the incomes and valuations of the members of their group for all units and the threshold value for each unit. The continuation rule was explained as follows. The individuals were to post their contribution to the provision of the good at stage 1. If the sum of the contributions was not sufficient to cover the cost, then the contributions would be returned and the game would end. If the sum met or exceeded the cost (threshold) the unit was supplied and the group went on to the next unit and so on until the sum of the contributions in that stage was insufficient to have the unit supplied. For this unit the contributions were returned. At this point the period ended. There was a maximum of 4 stages per period and the parameters were set such that the agents would be indifferent between having the fourth unit or not. The core allocation provided for 3 or 4 units of the good. This structure was constant across all treatments. The parameters (incomes, valuations, and thresholds) are provided in Appendix A.

In many experimental settings repetition is necessary to allow the subjects to "learn the game". For the experiments reported here the sessions were conducted for 15 periods in one treatment and for 6 to 8 periods in the other treatment. The repetition allows learning and it also provides the opportunity to test for conditions which affect the speed of convergence to equilibrium. In the single unit setting, Bagnoli and McKee found that convergence was slower for heterogenous groups. However, there is a question that there may be a repeated game effect when the subjects are assigned to the same group for a finite period game. Bagnoli and McKee confirmed that such effects were absent. One of the most important design questions is whether or not to scramble the subjects between rounds of the experiment. If one does not, then the subjects must view themselves as playing a finitely repeated game. If the "stage" game is the game that was solved, then technically, only the last round in the experiment is a test of the theory. Thus, the prior rounds cannot be used to evaluate the theory but do permit the subjects to gain experience with the game. This explains why many experimenters have switched to a methodology in which the subjects are scrambled between rounds. If done correctly, such scrambling allows all of the data to be used in testing the theory since the subjects have played a sequence of unrelated one-shot games. The disadvantage of scrambling is that one gives up any possibility of drawing inferences about the equilibria in the repeated setting. For example, in finitely repeated games, one subgame perfect equilibrium has the players playing the one-shot equilibrium in each period. By scrambling the subjects, one cannot learn whether the subjects playing the game are playing the one-shot equilibrium over and over. In the current paper we deal with this conflict differently by introducing "scrambling" of the subjects between rounds as a treatment.

In the experiments testing the single unit contribution game, Bagnoli and McKee chose not to scramble the subjects. For the multiple unit case, we felt that the extreme complexity suggested that scrambling was probably worthwhile. In addition, the computerized setting dramatically reduced the delays associated with scrambling. Hence, we ran both treatments to allow us to compare our results with those of the single unit experiments and to compare the scrambled and unscrambled treatments.

In the first treatment, the subjects were assigned to a single group for the duration of the session and they were told that this would be the case. In the second, the subjects were scrambled such that the group composition varied in each period. In this treatment the subjects played 2 practice rounds to begin with. The scrambling procedure consumed some time so we were unable to run as many periods as in the unscrambled treatment. Our results here are especially interesting since the multiple units game admits the possibility of many more equilibrium strategies than did the single unit game.

All group assignments are done via the software and the subjects were allocated to groups of five such that their nearest neighbors were not in their groups. The sessions which did not involve scrambling the subjects were told the session would run for 15 periods. In the sessions involving scrambling we did not inform the subjects of the total number of sessions in advance and we varied the number of periods.

All sessions were conducted in the LEAP (Laboratory for Economics and Psychology) facility at the University of Colorado. This facility consists of a dedicated MicroVAX and 16 terminals (one for the monitor) housed in a room in the psychology building. The terminals are located in booths which prevent the subjects from observing their neighbors' screens. Subjects were recruited from principles and intermediate economics classes. The instructions (provided in Appendix B) were read out loud while the subjects followed along on their copies (and practice sessions were conducted as described above). Questions were answered before the session began. With the payoff structure we utilized participants would earn approximately $1.30 per period if no units were supplied and upwards of $2.45 if three units were supplied. In practice subjects earned between $12.00 and $20.00 for their participation and appeared to be quite highly motivated.

4. Hypotheses and Empirical Evaluation

All groups have five individuals. From our sessions we have data on 6 groups from the "no scrambling" treatment and 11 groups from the "full scrambling" treatment. The aggregate contributions for the groups are reported in Appendix A. Due to space constraints, the data for the individual subjects are not presented here but are available from the authors.

Theorem 2 predicts that equilibrium behavior of the players will generate outcomes that are in the core. That is, the allocations that result will be Pareto optimal and individually rational. Testable hypotheses based on this theorem (given the parameters of our design) are:

Hypothesis 1:[6] The groups will provide three units of the good in each period.

Hypothesis 2: The contributions in each stage will sum to the threshold.

Hypothesis 3: The agents' contributions will be individually rational. In the context of SUSPE, this requires that the contributions be less than the valuation of the good at each stage.

Hypothesis 1 constitutes a fairly weak version of the prediction embodied in Theorem 2. It is possible to accept this

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[6] With the schedule of valuations such that the fourth unit is marginal we expect that risk averse agents will tend to fail to provide this unit.

hypothesis and have no allocations that are in the core since the aggregate contributions exceed the cost of the good. Nevertheless, it is worthwhile to begin our empirical assessment of the behavior of our subjects with this very weak test.

In general, the data provide some support for Hypothesis 1. That is, the groups are largely successful in providing the good at efficient levels.[7] Beginning with the data from the no scrambling sessions, we find that the groups are successful at having three units of the good provided in 50 of 90 observations (56%).[8] There are a further 6 cases where the third unit is not supplied but the contributions sum to 49 tokens or more. For the full scrambling treatment three units are supplied in 38 of 79 possible cases (48%). Again, there are 7 additional cases where the contributions for the third unit are between 49 and 50 tokens. In a little more than half of the possible cases we have three units being supplied.

This result might suggest that the individuals have some difficulty focussing on an equilibrium strategy. In some cases, the failure to supply three units can be traced to the behavior of one individual. The behavior that is most detrimental to the

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[7] We must reiterate that the game implements the core in that the allocations are PO and individually rational. There is no implication that <u>all</u> members of the group will post positive contributions. If the threshhold is met without agent j's contribution then the individually rational action of j is to contribute zero.

[8] Group 1 in the "no scrambling" treatment had considerable difficulty focussing on an equilibrium. As we will show later, this is due to the behavior of one individual. If we omit this group we find that the subjects supplied 3 units in 48 of 75 possible cases (64%).

group success occurs when an individual is very volatile in his choice of contribution. We will return to this issue in our discussion of Hypothesis 3.

If we look at the provision levels by unit[9] we find that our results are more in agreement with those of the theory (and the single unit cases). For the no scrambling treatment the good is provided in 189 of the 229 (83%) cases when the opportunity existed. Again, the results are comparable for the scrambling treatment where we find the good is provided in 166 of 214 (78%) cases.

However, the results from the multiple units setting are less robust than those of the single units experiments where the good was provided in 85 of the 98 cases where it was efficient to do so. The subjects in the single unit case played the strategies consistent with the refinement - undominated perfect equilibrium. In the multiple unit setting the stronger refinement does not appear to accurately capture the subjects' behavior.

Hypotheses 2 and 3 constitute the cornerstone of our evaluation of Theorem 2. The core allocation requires that the total contributions made by the group sum to the cost of the good for each of the units. Recall that when the contributions sum to more than 50 all members of the group will prefer a lower level of contribution. A glance at the data in the Appendix will indicate

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[9] In the single unit case reported by Bagnoli and McKee the subjects had the opportunity to contribute in all possible cases. The design of the multiple units setting does not allow this. If the group fails to provide the second unit they cannot go on to the third or the fourth. To adjust for this design feature we will report instances of contributions meeting or exceeding the threshhold as a fraction of the potential opportunities.

that all of the groups were not entirely successful in this regard. The total number of observations across groups, periods and stages is found by taking 3 stages per period, 15 periods, and the number of groups for each treatment. For the no scrambling treatment we observe the contributions summing to 50 (the announced threshold) in only 13 of 270 observations. For the full scrambling treatment the corresponding figure is 5 of 237 observations.

In much of laboratory experimental work, researchers argue for the use of a "band" or range of outcomes to define the equilibrium. This is because there are many coordination problems which make it difficult to achieve the theoretically predicted outcome exactly. In our case we will consider a range of the level of group contributions on the basis that there may be some coordination problems and that there may not be a clear focal equilibrium for those groups with different income and/or valuation distributions. If we take 47.5 to 52.5 as a range where the aggregate contributions are "close" to the predicted equilibrium then for the no scrambling treatment we find the aggregate contributions are within the band in 97 of 270. For the scrambling treatment the figure is 60 of 237. These scores are considerably worse than those for the single unit case where Bagnoli and McKee report that 53 of 98 observations were within the defined band.

The mean total contributions by stage (unit) for the "no scrambling" treatment are: unit 1 - 53.37 (5.77); unit 2 - 52.2 (6.22); unit 3 - 52.99 (4.79). In each case the aggregate contributions statistically exceed 50. The equilibrium predictions are based on risk neutral individuals. The "money back guarantee" is provided to mitigate the effects of risk aversion on the contribution behavior of the subjects. Given the rule for progression, the cost of falling short of the threshold is greater in the multiple unit setting than in the single unit setting. If the sum of the contributions does not cover the cost, the group loses the opportunity to advance to the subsequent units and earn the associated surpluses. It is not surprising that the aggregate contributions exceed the threshold here.

Individual rationality in our setting requires that no individual contribute more than the induced value of the good to that person. We introduce this as Hypothesis 3. As we have noted above, the data set comprised of individual behavior is too voluminous to include in this paper. Thus we will relate the results and repeat that the individual data are available on request.

We identify subjects as a/b indicating subject b in group a. The observation that the subjects are playing dominated strategies and/or strategies which are not strictly perfect is sufficient to refute hypothesis 3. A strategy which is clearly irrational is to contribute more than your valuation for each unit. Less obviously, another dominated strategy would be contributing in excess of your valuation in an early stage in an attempt to move the group on to later stages where this overcontribution can be recouped. We find no evidence of the former behavior and only weak evidence of the latter. Subject 1/5 did engage in a strategy which resulted in the group being unable to focus on an equilibrium. In round 4 this subject started to play a strategy which involved posting a very large contribution (not quite his valuation) for the first unit and then posting a contribution of zero for the next unit. The group seemed unable to adjust to this behavior with the result that it was only able to have the second unit supplied in one round after round 3. Since the group had been successful when 1/5 did not engage in such behavior, his new strategy is not strictly perfect and does not satisfy the refinement.

There are no other examples of such behavior in the no scrambling treatment nor are there any in the scrambling treatment. There are periodic instances of subjects apparently "experimenting" with different strategies in the no scrambling sessions. In the single unit experiments of Bagnoli and McKee it is apparent that the equilibrium selected did involve playing the same one-shot game equilibrium at each stage or round and there was a complete absence of individually irrational behavior once a "learning period" had elapsed. In general, in the multiple unit case we find some support for Hypothesis 3. The individuals are playing strategies which are individually rational but in the unscrambled setting they do not seem to be playing the same one-shot game equilibrium.

Since we induce all values we are able to compute the level of group welfare attained by each group in the sessions. These figures are reported in Appendix A. With the exception of G1 NS the groups under the "no scrambling" treatment attained better than 66% of the theoretical maximum welfare level.[10] The results for the scrambling treatment are less robust. Here the welfare levels are closer to 50% of the theoretical level with the exception of G11 S. A Mann-Whitney test yields the result that the efficiency scores are lower for the scrambling treatment. The z-statistic is 2.27.

5. Conclusions and Remarks

We find some support for the theorem that the agents will play the refined strategies necessary to achieve an equilibrium that is in the core. Overall, the rate of success is much less than in the single unit experiments reported by Bagnoli and McKee. Indeed, from the aggregate results reported above it is clear that the multiple units game is much less likely to implement the core than the single unit game. Thus, our results raise serious questions about the predictive success of Bagnoli and Lipman's Theorem 2. For the multiple unit case, it does not appear that the contribution game they studied is likely to generate core allocations. That is, unlike the single unit case where a core outcome is likely if that contribution game is employed, this is much less likely to occur in the multiple unit case.

From a policy perspective this is a disappointing result. Since many of the other incentive compatible mechanisms have

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[10] G1 NS is, of course, the group in which one individual adopted a strategy that was clearly not compatible with the refinement to the Nash equilibrium. Further, in G1 NS the group was comprised of individuals with different payoffs to the public good. From the work of Bagnoli and Mckee it appears that this type of heterogeneity is difficult for the group to deal with.

substantial administrative requirements and generate budget surpluses which must be disposed in a manner which will not affect the allocation of resources, the search for a voluntary provision scheme seems worthwhile. Our experiments show that Bagnoli and Lipman's scheme, which theoretically yields efficient outcomes, appears not to work well in practice. The difference in practical usefulness between Bagnoli and Lipman's single and multiple unit games raises questions for the class of games investigated by Dawes and others. In previous work these games were applied to a binary output decision and, to date, these games have not been evaluated in multiple unit settings. This is a worthy topic for future research.

We do wish to note that the mechanism performed much better than we expected. The subjects face a complicated task and the refinement required to implement the core is quite strong.

From the welfare levels data it is clear that some groups were able to focus on an equilibrium and stick with this. Group 4 in the no scrambling treatment is a case in point. This group generated welfare levels very close to the theoretical maximum. In general, however, the welfare levels achieved even in the later rounds are well below the theoretical levels.

It remains for us to briefly investigate whether some features of the experimental design are responsible for the results we have obtained. For the no scrambling treatment the subjects were required to make many more decisions than those in the single unit setting of Bagnoli and McKee. Each unit requires the same decision as each stage of the single unit setting. In addition, the strategy space is much larger in the multiple unit setting.

Both of these factors may have led the subjects to "experiment" with different strategies. Inspection of the results reported in Appendix A shows that the groups were least successful in the middle rounds of the no scrambling sessions. Indeed, the average welfare level, by period, for periods 1 through 5 was 79.62; for periods 6 through 10 was 73.93; and for periods 11 through 15 was 79.29. It appears that after some experimentation, which lead to failure to implement the efficient solution, the groups returned to their previous equilibrium strategies. The welfare levels in the middle rounds are statistically lower at the 93% level or better.

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Appendix A
Data

Aggregate Group Contributions

"No Scrambling Treatment"

	G1 NS Stages				G2 NS Stages			
Period	1	2	3	4	1	2	3	4
1	54.00	53.00	47.00	-	51.25	54.45	50.75	55.00
2	52.00	54.00	57.00	59.00	50.25	53.25	51.00	40.00
3	59.00	56.00	54.00	37.00	53.25	51.25	52.00	42.50
4	49.00	-	-	-	52.00	50.75	53.25	31.00
5	54.00	42.00	-	-	48.75	-	-	-
6	57.00	43.00	-	-	53.50	54.75	57.00	32.50
7	50.00	33.00	-	-	47.25	-	-	-
8	55.00	31.00	-	-	54.50	44.00	-	-
9	50.00	39.00	-	-	56.79	65.66	49.70	-
10	52.00	30.00	-	-	55.34	53.91	41.25	-
11	48.00	-	-	-	50.75	56.00	54.00	35.50
12	42.00	-	-	-	51.35	52.90	58.25	26.00
13	64.00	44.00	-	-	52.74	52.51	54.15	25.10
14	55.00	48.00	-	-	48.00	-	-	-
15	54.00	60.00	48.00	-	56.50	58.25	53.50	39.00
mean	53.01	44.42	-		52.15	53.97	52.26	-
std	5.11	10.05			2.92	5.05	4.46	

	G3 NS Stages				G4 NS Stages			
Period	1	2	3	4	1	2	3	4
1	89.00	52.50	55.50	44.50	55.00	53.00	49.00	-
2	47.50	-	-	-	55.00	53.00	53.00	41.00
3	70.50	51.50	51.00	44.50	56.00	53.00	54.00	45.00
4	53.00	58.00	52.00	46.00	54.00	51.00	55.00	38.00
5	51.00	55.50	52.00	55.00	47.00	-	-	-
6	52.00	53.00	50.00	54.00	50.00	53.00	51.00	55.00
7	51.00	53.00	49.50	-	51.00	52.00	52.00	51.00
8	52.00	53.50	52.20	52.80	49.00	-	-	-
9	51.50	52.50	48.60	-	52.00	53.00	50.00	50.00
10	50.50	55.00	47.50	-	52.00	51.00	52.00	50.00
11	50.50	54.00	56.00	49.00	51.00	52.00	51.00	50.00
12	51.50	58.00	56.00	49.00	51.00	51.00	50.00	49.00
13	50.50	53.00	49.50	-	52.00	39.00	-	-
14	49.50	-	-	-	50.00	51.00	50.00	52.00
15	55.30	52.70	54.50	49.50	51.00	51.00	49.00	-
mean	55.02	54.02	51.87	49.92	51.67	51.00	51.33	48.10
std	10.76	2.06	2.88	4.22	2.47	3.72	1.92	5.22

	G5 NS				G6 NS			
	Stages				Stages			
Period	1	2	3	4	1	2	3	4
1	61.00	60.50	45.00	-	51.00	46.00	-	-
2	66.50	65.00	62.50	46.00	53.00	57.00	52.50	48.00
3	59.50	56.50	65.00	61.00	52.00	53.00	50.00	48.00
4	61.00	54.50	56.00	39.50	49.00	-	-	-
5	55.00	56.00	51.00	48.00	55.00	52.50	49.00	-
6	54.50	56.50	55.00	50.00	53.00	53.00	54.50	45.00
7	52.50	50.00	54.00	57.50	51.00	52.00	48.00	-
8	53.00	53.00	59.00	52.00	52.00	50.00	56.50	41.00
9	51.00	50.00	61.00	50.00	49.00	-	-	-
10	49.50	-	-	-	49.00	-	-	-
11	63.00	52.00	60.50	41.50	54.00	52.00	53.00	43.00
12	59.50	53.50	41.00	-	52.00	53.00	53.00	37.00
13	56.50	59.50	60.00	44.00	48.00	-	-	-
14	51.00	62.00	64.00	38.00	51.00	55.00	53.00	29.00
15	61.50	54.50	64.00	34.20	51.00	52.00	53.00	39.50
mean	57.00	55.96	57.00	46.81	51.33	52.32	52.25	
std	5.11	4.45	7.25	7.93	1.99	2.76	2.56	

Aggregate Group Contributions

"Full Scrambling Treatment"

	G1 FS Stages				G2 FS Stages			
Period	1	2	3	4	1	2	3	4
1	60.00	40.00	-	-	51.00	49.50	-	-
2	60.00	57.00	48.00	-	74.50	54.25	47.20	-
3	60.00	57.00	58.00	58.00	63.05	59.50	58.00	51.00
4	58.00	51.50	49.50	-	55.00	56.00	48.00	-
5	45.00	-	-	-	60.50	50.50	45.50	-
6	63.00	52.50	45.00	-	52.30	50.20	53.50	35.00
7	58.00	53.00	53.00	50.00	67.00	61.50	58.50	43.00
8	53.50	52.30	51.70	43.50	54.00	58.00	52.00	43.00

	G3 FS Stages				G4 FS Stages			
Period	1	2	3	4	1	2	3	4
1	64.00	51.00	49.00	-	53.50	51.00	49.00	-
2	59.00	56.00	51.00	19.50	57.00	53.50	52.00	-
3	55.00	56.00	54.00	31.00	53.00	52.50	53.00	48.50
4	48.00	-	-	-	53.00	54.00	52.00	55.50
5	58.00	52.00	52.00	42.00	52.00	56.50	50.00	46.00
6	59.00	47.00	-	-	55.50	58.80	54.00	48.00

	G5 FS Stages				G6 FS Stages			
Period	1	2	3	4	1	2	3	4
1	53.00	53.00	49.50	-	62.50	55.60	46.10	-
2	54.50	53.50	59.00	48.50	61.00	51.50	52.50	29.50
3	56.30	53.00	59.80	63.00	53.00	48.00	-	-
4	54.00	54.50	49.00	-	53.00	54.90	57.00	35.00
5	52.50	57.50	52.00	13.50	56.00	52.50	54.00	28.50
6	52.50	56.50	52.00	18.00	51.00	49.00	-	-
7					57.50	53.00	51.00	12.00

	G7 FS Stages				G8 FS Stages			
Period	1	2	3	4	1	2	3	4
1	62.00	61.50	54.75	45.75	48.00	-	-	-
2	44.50	-	-	-	64.00	61.50	50.00	15.00
3	54.25	53.75	51.50	34.50	50.50	58.50	47.50	-
4	58.50	52.50	44.50	-	55.50	52.00	52.00	10.00
5	52.70	50.50	47.50	-	55.50	46.00	-	-
6	52.50	51.00	46.50	-	50.50	49.50	-	-
7	62.50	55.50	49.00	-	60.50	48.50	-	-

	G9 FS Stages			
Period	1	2	3	4
1	46.00	-	-	-
2	56.50	50.00	54.00	36.00
3	59.00	54.50	45.00	-
4	51.00	45.50	-	-
5	60.00	45.00	-	-
6	48.00	-	-	-
7	58.90	57.30	57.50	27.00
8	55.70	54.20	52.40	27.00

	G10 FS Stages			
Period	1	2	3	4
1	44.00	-	-	-
2	55.00	52.00	48.50	-
3	45.50	-	-	-
4	49.00	-	-	-
5	52.50	56.50	53.50	30.40
6	52.00	53.00	55.00	33.00
7	48.00	-	-	-
8	55.00	50.00	52.00	10.00

	G11 FS Stages			
Period	1	2	3	4
1	54.00	50.00	59.00	45.00
2	55.00	51.00	47.00	-
3	59.00	56.00	57.00	45.00
4	53.50	53.00	53.00	42.00
5	51.00	52.00	53.00	45.00
6	50.50	50.50	49.00	-
7	53.00	54.00	46.00	-
8	55.00	56.00	58.00	-

Welfare Levels

"No Scrambling Treatment"

Round	G1 NS	G2 NS	G3 NS	G4 NS	G5 NS	G6 NS	Theory
				Groups			
1	83.0	113.5	73.0	82.0	68.5	49.0	120.0
2	107.0	115.0	-	109.0	76.0	107.5	120.0
3	101.0	114.5	97.0	107.0	90.0	115.0	120.0
4	-	114.0	107.0	111.0	99.5	-	120.0
5	46.0	-	112.5	-	108.0	82.5	120.0
6	43.0	104.8	115.0	116.0	104.0	109.5	120.0
7	50.0	-	86.0	115.0	113.5	87.0	120.0
8	45.0	45.5	112.3	-	105.0	111.5	120.0
9	50.0	67.6	86.0	115.0	108.0	-	120.0
10	48.0	80.8	84.5	115.0	-	-	120.0
11	-	109.3	109.5	116.0	94.5	111.0	120.0
12	-	107.5	104.5	118.0	78.0	112.0	120.0
13	36.0	110.6	86.5	48.0	95.0	-	120.0
14	45.0	-	-	119.0	93.0	111.0	120.0
15	76.0	101.8	107.5	89.0	89.2	114.0	120.0
Σ_a	730.0	1184.7	1281.3	1360.0	1241.2	1110.0	1800.0
Σ_b	157.0	429.1	408.0	490.0	449.7	448.0	600.0

Note: Σ_a refers to the aggregate over all 15 periods.
Σ_b refers to the aggregate over the last 5 periods.

"Scrambling Treatment"

Round	G6 S	G7 S	G8 S	G9 S	G10 S	G11 S	Theory
				Groups			
1	71.9	101.8	-	-	-	107.0	120.0
2	105.0	-	95.5	109.5	83.0	84.0	120.0
3	47.0	110.5	81.0	76.5	-	98.0	120.0
4	105.1	79.0	110.5	49.0	-	110.5	120.0
5	107.5	86.8	44.5	40.0	107.5	114.0	120.0
6	49.0	86.5	49.5	-	110.0	89.0	120.0
7	108.5	82.0	39.5	96.3	-	83.0	120.0
8	n/a	n/a	n/a	107.7	113.0	101.0	120.0

Initial Data: Incomes & Valuations

The distributions of incomes and valuations are generated within the software according to the following mapping:

Income Distributions
(Shares of Total Income)

Subj#	1	2	3	4	5
a)	0.20	0.20	0.20	0.20	0.20
b)	0.28	0.28	0.15	0.15	0.14
c)	0.28	0.24	0.20	0.14	0.14
d)	0.22	0.22	0.22	0.22	0.14

Payoff Distributions
(Shares of Total Payoff)

Subj#	1	2	3	4	5
x)	0.20	0.20	0.20	0.20	0.20
y)	0.30	0.30	0.15	0.15	0.10
z)	0.30	0.20	0.20	0.20	0.10

Then the income-payoff combinations are selected as initial conditions.

Income-Payoff Combination #3 is comprised of income distribution a) and payoff distribution z). Income-payoff Combination #4 is comprised of income distribution a) for group 1 of the session (three groups run at one time), b) for group 2, and c) for group 3 and payoff distribution x).

G1 NS, G2 NS, and G3 NS used income/payoff combination #4.

G4 NS, G5 NS, and G6 NS used income/payoff combination #3.

Appendix B

Experimental Instructions - No scrambling case

Experimental Instructions

This is an experiment in decision making. Several research organizations have provided funds for this research. Read the instructions carefully. If you follow them and make good decisions, you may earn a considerable amount of money. This money will be paid to you in cash at the end of the experiment.

Organization

You have been organized into groups of five persons. Each group will consist of the same five persons for the duration of the session. The specific identities of the other persons in your group will not be revealed to you. You may not communicate with anyone else in the room during the session. Failure to observe this instruction will result in the termination of the experiment and the forfeiture of all monies earned.

The whole session will last for fifteen periods each of which will be comprised of several stages. At each stage during each period you will be required to make a decision and your total earnings for the session will depend on these decisions.

At the beginning of each period the screen will announce to you the income you will receive in tokens for the period. These tokens will be exchanged for money, at the rate of ____ cents per token, at the end of the session. Also provided on the screen is the income of each of the other persons in your group. This information may vary from period to period so read it carefully each period.

For each stage you will be asked to post a contribution. If the sum of the contributions from the group meets or exceeds the threshold level reported on the screen the group will receive an additional bundle of tokens to be shared by all the members of the group regardless of their actual contributions. The actual shares to each person are reported on the screen as part of your information.

Each period will proceed as follows. You will receive a new income in tokens. For Stage 1 you will post a contribution. If the sum of the contributions for the group meet or exceed the threshold for the stage the additional tokens will be provided. If the threshold is met at Stage 1 you will go on the Stage 2. If the threshold is met at Stage 2 the second bundle of additional tokens will be provided and the group will go on to Stage 3 and so on until the sum of the contributions from the group does not meet the threshold. At this point the period ends and a new period will begin.

At each stage you will be informed of your remaining income at this stage. This is calculated by subtracting your contributions to successful provision of the additional bundles from your

initial income. Your share of the bundles of additional tokens is not provided to you until the end of the period. Thus, your share of the additional tokens
cannot be used to contribute to the provision of additional bundles.

Contributions in excess of the threshold are kept by the persons running the experiment. For the Stage at which the threshold is not attained your contributions are returned. Thus your income for the Period is computed as follows: your initial income @i(plus) your accumulated shares of the additional tokens for those stages in which they are supplied @i(minus) the sum of your actual contributions in those periods for which the threshold is met or exceeded.

There are some simple rules regarding the contributions you may post. You may enter any contribution from zero up to the level of your income for the PERIOD minus your PREVIOUS CONTRIBUTIONS for the period. Contributions in excess of your current net income will not be accepted. Enter your contribution at the terminal in numbers. You may contribute part tokens, e.g. 0.5 tokens or 4.3 tokens. You will have two minutes to decide on your contribution and to enter it.

Once the contributions have been entered, the computer will compute the totals for each group. If the sum of the contributions meets or exceeds the threshold level for that stage the bundle of additional tokens will be provided to the group and your share will be paid to your account. You will be informed by the computer of the TOTAL contribution of your group but not the contributions of the individual members. You will be informed of the remaining balance of each of the members of your group. If the threshold for the current stage is met or exceeded the computer will automatically proceed to the next stage.

We have provided a sample screen and session which will be presented when you have all finished reading these instructions. Any questions will be answered once the sample session has been presented.

SAMPLE SCREEN

INFORMATION SCREEN

Period #1 ID # 2

(5 Persons per proup,
4 Stages per period)

The INCOMES for this period:

yours 30 tokens
others 30 30 30 30 tokens

THRESHOLD CONTRIBUTION of your group for each stage is 50 tokens

If this threshold is met or exceeded, the group will receive the following additional tokens

	Stage 1	Stage 2	Stage 3	Stage 4
Your Share	20	18	15	10
others´	20	18	15	10
	20	18	15	10
	20	18	15	10
	20	18	15	10
Group Total	100	90	80	50

CONTRIBUTION

Period #1, Stage #1
Your Balance = 30.0
Enter your
Contribution
--->

RESULTS

The group contributed a total of ___ tokens

The good ______ provided at this stage

Your returns for the period are ___ tokens
(To be distributed at the end of the period)

MESSAGE

The Screen

The screen is comprised of 4 parts and is divided into boxes. The large box on the left is the Information Screen and it shows the period at the top. Next you see the income for yourself and for the other members of your group. You are informed of the group's THRESHOLD CONTRIBUTION (here 50 tokens) and your own payoff if the threshold is met or exceeded for each of the potential stages for this period. At the bottom you see the total payoff for the group for each stage.

At the top of the right side of the screen you see the box marked "Contribution". This informs you of the period and the stage, your current balance for the period and asks you to enter your contribution.

The middle box on the right side reports the RESULTS. Once all of the members of your group have posted their contributions the computer sums these contributions and will tell you the total and whether the additional bundle of tokens (the "good") is provided at this stage. This box also informs you of your returns for the period.

The final box marked "Message" is reserved for telling you when you should push the RETURN key to move along in the session.

The Session

A session might proceed as follows. For Period 1, Stage 1 say you post 11 tokens as your contribution. The total for your group is 54 which exceeds the threshold so you receive the message in the RESULTS box that the additional tokens are provided. The Group proceeds to Stage 2. Your current income is 19 tokens (your original income of 30 tokens minus the 11 you posted at Stage 1). You post a contribution of 8 tokens. This time the total for the group is 38 which is less than the threshold. This time the RESULTS box gives you the message that the additional tokens are not provided and your contribution is returned. One additional bundle of tokens has been provided in this period.

For Period 1 your total income is 30 plus 20 minus 11 = 39 tokens. And this is added to your account to be paid at the end of the session.

Now you would proceed to the next period.

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