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Threshold, public good, rebates, experiment

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ALTERNATIVE REBATE RULES
IN THE PROVISION
OF A THRESHOLD PUBLIC GOOD:
AN EXPERIMENTAL INVESTIGATION

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Alternative Rebate Rules in the Provision of a Threshold Public Good:
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Abstract

This study reports the effects of rebate rules on voluntary contributions to a threshold public good. Rebate rules specify how excess contributions, over the threshold amount required to provide the public good, are distributed. We examine three rebate rules experimentally: a no rebate policy where excess contributions are discarded, a proportional rebate policy where excess contributions are rebated proportionally to individual's contributions, and a utilization rebate policy where excess contributions provide some continuous public good. Significantly more Nash equilibrium outcomes are observed under the no rebate treatment than under either of the other two. Interestingly, the variance of contributions is significantly different between the three treatments; highest under the utilization rebate policy and lowest under the no rebate policy.

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Alternative Rebate Rules in the Provision of a Threshold Public Good: An Experimental Investigation

1. Introduction

In 1995 the Niagara Mohawk Power Company of New York introduced the Green Choice program. Citizens in upstate New York could opt to join the program through a commitment to pay an additional fixed fee each month that would be added to their electric bill. Fees would be collected for a twelve month period and, if enough were collected, would be used to build an environmentally friendly energy project. Since this energy project had an associated price tag, a certain minimum number of subscribers to the Green Choice Program were required. If subscriptions fell short of the needed level, the program would be abandoned and the funds previously collected, returned. The Green Choice program is an example of a simplified provision point mechanism designed to fund a threshold public good.[1]

In a provision point mechanism, the size of a proposed project and the associated total cost are predetermined (this cost threshold is referred to in the literature and in this paper as the provision point). Members of the community impacted by the project submit bids stating their dollar commitment to covering the project costs. If the sum of contributions covers the cost of the project, it is funded, otherwise it is not.[2]

Because individuals receive benefits upon meeting *or exceeding* the contribution threshold, the provision point mechanism lends itself to potential over contribution. For example, Niagara Mohawk might find that they collect *more* than the necessary funds to build the renewable energy project.[3] Therefore, the rules of the mechanism must specify the distribution of

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[1]We thank William Schulze for bringing the Niagara Mohawk Green Choice Project to our attention. For more details on this program see Schulze (1995).

[2]The provision point mechanism itself specifies neither a refund nor a rebate mechanism. The refund mechanism describes how money collected is refunded when the provision point is not met. In this study we use a money back guarantee procedure. If the provision point is not met, all contributions are returned to their contributors. In contrast, the rebate procedure describes how money collected over and above the provision point is rebated to contributors.

[3]This problem of collecting too many funds was recently threatening the city of Seattle, where lottery tickets marketed to finance a new stadium for the Seattle Mariners were selling well above expectation. The lottery was

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any such excess contributions. It is this institutional feature, which we will refer to as "rebate rules," that is explored in this paper.[4]

This study reports the results of an experiment involving the voluntary provision of threshold public goods. We examine three principal rebate approaches.

The first and simplest is a *No Rebate* policy in which excess contributions are simply wasted. This wastage can be interpreted literally, as throwing the extra funds into the ocean, or figuratively, when those funds are spent on goods which provide no utility to the contributors. For example, Niagara Mohawk might choose to use excess contributions for decorating the offices of their employees. Since the money is essentially lost from the perspective of the contributors, the No Rebate policy involves the strictest penalties for over contribution.

The second rebate rule is a *Proportional Rebate* policy, in which excess contributions are distributed back to contributors in proportion to their individual contributions. This rule involves weaker penalties for over contribution than does the No Rebate policy, and the penalty varies with the amount contributed by each individual and by the group.

The third rebate rule is the *Utilization Rebate* rule in which excess contributions are used to provide more of the public good in a continuous manner. For example, Niagara Mohawk could use excess contributions to plant trees.[5] While the Utilization rebate policy involves some penalties for over contribution, they are not nearly as harsh as the No Rebate policy and are generally smaller than the penalties from the Proportional Rebate policy.

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obligated to contribute $3 million toward the cost of the stadium, but in the first eight days of sales, the tickets had raised $582,000. If all the year's tickets were sold, the lottery would bring in $3.9 million. The rebate mechanism would describe how the excess $900,000 would be spent. The Associated Press reports that "[t]he surplus will be paid into the state's general fund . . .". quoted from ClariNet (1996).

[4]It is important to distinguish between the institutional feature that we refer to as rebates and the feature of refunds. Refund rules apply when the contribution level is less than the threshold amount and the project is not provided. Rebate rules apply when the contribution level *exceeds* the required threshold and the project is provided. Excess funds can be rebated back to contributors according to some prespecified rule.

[5]In fact, the current version of the Green Choice Program involves a very similar provision.

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With the parameter values we choose, and under all three rebate policies, the provision point mechanism game has a continuum of Nash equilibria in which the provision point is exactly met. Each equilibrium in the continuum specifies how the costs of providing the public good are divided among the contributors.

The rebate feature seems to be an important part of a public goods provision point mechanism. However, theoretical discussion of rebates in the literature is sparse. The idea of rebates is first discussed in Smith (1980) who presents an experiment using two rebate options in the investigation of an auction mechanism for public goods provision. Unfortunately, he does not report differences between the alternate rebate mechanism. Bagnoli and Lipman (1989) suggest that rebate policies should have the property that an increase in contribution of $1 by individual i should not generate a refund to individual i of more than $1. All three policies we examine have this property.

This paper offers three important contributions. First, it explores an institutional feature of voluntary public goods provision, the rebate feature, which has not yet been investigated. Knowledge of the importance of this feature will aid economists in furthering their understanding of public goods mechanisms and policy makers in selecting policy implementations. Second, it offers further experimental evidence of the usefulness of the provision point mechanism for providing public goods, an area where experimental study is very limited. And third, the results of this study help to explain discrepancies between the two existing provision point mechanism studies, Isaac, Schmidtz, and Walker (1989) and Bagnoli and McKee (1991).

These two studies make up the bulk of experimental work in provision point mechanisms and involve strikingly different results. Bagnoli and McKee report subjects playing the efficient Nash equilibrium (in which the provision point is exactly met) 54% of the time. In Isaac, *et al.'s* medium provision-point sessions (the ones most comparable with Bagnoli and McKee and this study) only 3% of the observations are Nash equilibria. There are many procedural differences between the two studies; group sizes, average net earnings from the public good, framing of the

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instructions and informational environments. However, the results from this paper argue that the driving difference between the frequency of equilibria play observed in the two papers is the use of rebate mechanism. Bagnoli and McKee use a no-rebate policy while Isaac, *et al.* use a utilization rebate policy. In this study, the no-rebate policy had significantly higher equilibrium play than the utilization rebate did.

The organization of this paper is as follows. In section 2 we discuss the game and various rebate mechanisms. Section 3 describes the experimental parameters and procedures. Section 4 outlines some conjectures while Section 5 presents the experimental results and analysis. Section 6 concludes.

2. The Game and Rebate Mechanisms

Imagine a group of size N, in which each individual has an endowment E_i, and a valuation for a threshold public good v_i. Individuals allocate some portion of their endowment toward funding the public good, σ_i. The cost of providing the public good is PP. If $\Sigma\sigma_i \geq PP$ then the public good is provided. If not, the public good is not provided and all contributions are returned.

Individual payoffs in this game differ with the different rebate policies. The individual payoff functions (π_I) and associated marginal costs of over contribution for the three policies are derived below.

A. No Rebate Policy

$$\pi_i = (E_i - \sigma_i) + v_i \qquad\qquad \text{if } \Sigma\sigma_i \geq PP$$

$$\pi_i = E_i \qquad\qquad \text{otherwise}$$

Under the no rebate policy, any surplus allocated to the public good disappears. Thus if the public good is provided (with or without excess funds), each player receives the payoff from their private consumption, and their value (v_i) for the public good. If the public good is not provided, contributions are returned and players receive payoff from their private consumption

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only. The penalty associated with over contribution imposed on individual i is calculated by the partial derivative

$$\frac{\partial \pi_i}{\partial \sigma_i} = -1$$

implying that the additional unit of endowment contributed to the public good beyond the provision point level (PP) by individual i is wasted. It may help to think of making excess contributions in the No Rebate treatment as a negative-sum activity; no player receives any benefit from the excess contributions, and the player who made them is worse off.

B. *Proportional Rebate Policy*

$$\pi_i = (E_i - \sigma_i) + v_i + \frac{\sigma_i}{\Sigma \sigma_i}(\Sigma \sigma_i - PP) \qquad \text{if } \Sigma \sigma_i \geq PP$$

$$\pi_i = E_i \qquad \text{otherwise}$$

Under this rebate policy if the public good is provided, players receive payoff from their private consumption of their remaining endowment as well as their value for the public good. In addition, they receive a share of any excess contributions for private consumption. Their share is set equal to the proportion of their contribution to the public good. If the public good is not provided, players again receive payoff from privately consuming their endowment.

The penalty associated with over contribution is

$$\frac{\partial \pi_i}{\partial \sigma_i} = -1 + \frac{(\Sigma \sigma_i)^2 - PP(\Sigma \sigma_i - \sigma_i)}{(\Sigma \sigma_i)^2}$$

where

$$0 \leq \frac{(\Sigma \sigma_i)^2 - PP(\Sigma \sigma_i - \sigma_i)}{(\Sigma \sigma_i)^2} \leq 1$$

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The penalty for over contribution under the proportional rebate policy changes over the range of individual and group contributions.[6] It may help to think of making excess contributions in the Proportional Rebate treatment as a constant-sum activity; excess contributions can be characterized as transfers from the player who made them to the other players in his group.

C. Utilization Rebate Policy

Under the utilization rebate policy, contributions generated over and above those necessary for provision of the public good are used to provide more of a similar but continuous public good. In the Green Choice Program, for example, funds raised in excess of those needed to construct the project could be used to plant trees. One more parameter is needed to describe the utilization rebate policy; the marginal value to the individual of this continuous public good. Call that value w_i. Now we can describe

$$\pi_i = (E_i - \sigma_i) + v_i + w_i(\Sigma\sigma_i - PP) \qquad \text{if } \Sigma\sigma_i \geq PP$$

$$\pi_i = E_i \qquad \text{otherwise}$$

If the public good is provided each player receives in addition to the payoff from their private consumption and their value for the public good, their value from the utilization rebate (zero when the provision point is exactly reached and $\Sigma\sigma_i = PP$, positive otherwise).

The penalty associated with over contribution is calculated by the same derivative, but now has the form

$$\frac{\partial\pi_i}{\partial\sigma_i} = -1 + w_i$$

implying that while a marginal unit of endowment allocated to the public good over the level of PP is not wasted, it nonetheless would be better spent in private consumption whenever $w_i \leq 1$.

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[6]Under this rebate mechanism, an extra token contributed by player i is not wasted (as in the No Rebate treatment) but instead redistributed among all the players in proportion to their contributions. Although an individual's payoff from *his* contribution of an extra token is negative, the other players in his group receive positive payoff from his over contribution. To see this we only need note that

$$\frac{\partial\pi_i}{\partial\sigma_j} = \frac{PP\sigma_i}{\Sigma\sigma_i} \geq 0 \quad (= 0 \text{ only when } PP = 0 \text{ or } \sigma_i = 0)$$

This condition is exactly the one discussed in Bagnoli and Lipman; that an increase in contribution of one unit by individual i should not generate a refund to individual i of more than one unit.

Under this rebate treatment, if $w_i \leq 1$ and $\Sigma w_i \geq 1$, over contribution can be viewed as voluntary contribution to a continuous public good. Making excess contributions in the Utilization Rebate treatment under this parameterization is a positive-sum activity; excess contributions *do* make the group as a whole better off, albeit at the expense of the contributor.

D. Equilibria of the Game

The set of Nash equilibria in this game are the same under any of the three rebate policies. In each game there exists a continuum of efficient Nash equilibria in which the players contribute exactly enough to achieve the provision point and provide the public good ($\Sigma \sigma_i = PP$). These equilibria have the same group contribution level, and are not pareto-rankable. They are distinct from one another only in the cost-sharing rule used to divide the costs of the public good among the participants.

In addition, there are a continuum of pareto-dominated equilibria of this stage game in which the provision point is not met and the public good is not provided, characterized in the next section. These equilibria were observed in only two instances out of 300.

3. Experimental Parameters and Procedures

All sessions of the experiment were performed in a non-computerized laboratory at Texas A&M University. Each of the three rebate policy treatments involved four experimental sessions of one group of five subjects (N=5). Each session involved subjects playing the public goods game repeatedly for 25 periods.

In each period, all individuals were endowed with 55 tokens ($E_i = 55$). Subjects were asked to divide their endowment between two types of accounts: a Private Account and a Group Account. The group account parallels contributing toward providing the public good (their contribution to the group account is σ_i). The private account parallels private consumption. For

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each token allocated to their private account, a subject received 1¢ per token. Tokens allocated to the group account were totaled and compared with the provision point of 125 tokens (PP=125).

Each subject's value for the public good was $v_i = 50$¢. Thus each subject received 50¢ if the provision point was reached by the group. If it was not reached, each subject received their contribution (σ_i) back. These tokens were assumed to be invested in the private account and earned 1¢ per token.

In the event of a surplus of tokens in the group account, the rebate feature specifies their distribution. The marginal value for the continuous public good in the utilization rebate treatment was $w_i=2/N$; thus in that treatment each individual received .4¢ for each token allocated to the group account above and beyond 125. Notice that $w_i \leq 1$ and $\Sigma w_i \geq 1$, as discussed above.[7]

With these parameter values we can calculate the marginal penalties from over contribution in each of the three treatments. As before, in the No Rebate treatment the cost to an individual of over contribution by one token is

$$\frac{\partial \pi_i}{\partial \sigma_i} = -1.$$

In the Proportional Rebate treatment that cost is

$$\frac{\partial \pi_i}{\partial \sigma_i} = -1 + \frac{(\Sigma \sigma_i)^2 - 125(\Sigma \sigma_i - \sigma_i)}{(\Sigma \sigma_i)^2}.$$

where this cost is bounded between 0 and 1 and depends on any given subject's contribution to the group account as a proportion of the total amount contributed. Finally, in the Utilization Rebate treatment the cost of over contribution by one token is

$$\frac{\partial \pi_i}{\partial \sigma_i} = -1 + .4 = -.6.$$

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[7]This value for w_i is consistent with the ratio of the value to the cost of the threshold public good. The cost of the public good is 125 tokens while the return from it is 250 tokens divided equally among the participants.

Under a very broad range of contribution distributions, the penalty from over contribution in the Proportional Rebate treatment falls between those in the No Rebate and Utilization Rebate treatments (between -1 and -.6). Of the 500 individual decisions made in the Proportional Rebate treatment of this experiment, the penalty fell outside this range only 15 times (3%).[8]

All experimental instructions were written so that they conform to language developed by Isaac, Walker, and Thomas (1984). All language referring to "investments" or "contributions" was intentionally avoided and replaced by words such as "allocation" of tokens. Common information was established by reading instructions out loud and using an overhead projector.

After each decision period the total Group Account allocation was announced verbally and was displayed on an overhead. Subjects played the public goods game with one rebate treatment for 25 periods.

The set of efficient equilibria of the stage game involve each group of five subjects allocating exactly 125 tokens to the group account. Additionally, this stage game has a unique symmetric efficient equilibrium in which each of the five members of the group allocates 25 tokens to the group account. Previous research suggests that this equilibria may serve as a focal point, see Schelling (1960), and the frequency of its occurrence will be analyzed below.

The stage game also has a continuum of inefficient equilibria, in which the public good is not provided. Out of 300 group decisions, only two instances of these inefficient equilibria were observed.[9]

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[8]Furthermore, those 15 decisions are all attributable to three subjects who consistently contributed more to the public good than their valuation for it.

[9]There are a number of pareto-dominated equilibria in which somewhere between 0 and 86 tokens are allocated to the group account, but no player can unilaterally supplement the account to achieve the provision point. Thus all tokens are returned to the players who are then indifferent between any allocation. An example of this equilibria is a vector of allocations to the group account like (16,16,16,16,16) (an asymmetric example is (6,14,19,20,21)). Here 80 tokens have been allocated, but no one player has the necessary 45 tokens to unilaterally supplement the group account to achieve 125. No equilibrium of this sort exists in which 87 - 124 tokens are contributed, and only two instances of this equilibrium were observed out of the 300 group decisions.

4. Hypotheses and Informal Conjectures

A. *Group Contributions*

The set of Nash equilibria in the public goods game under each of these three rebate mechanisms are the same. While the efficient Nash equilibria predictions do not generate a unique cost sharing rule, they do generate a unique aggregate contribution level. The first conjecture outlined in this subsection involves whether any element of this set of equilibria is played.

> Conjecture 1 (NE): Groups in all treatments will play an efficient Nash equilibrium, thus the aggregate level of contributions will equal the provision point level of contributions (PP=125) in all three rebate treatments.

Although Conjecture 1 describes the set of Nash equilibria of the game, groups may find it difficult to coordinate on a particular equilibrium out of the set. If this coordination failure is prevalent we might expect Conjecture 1 to be invalidated. However, economic theory makes few predictions of what will occur in place of equilibrium behavior.

A second conjecture addresses these predictions and competes with Conjecture 1. It suggests that the magnitude of the penalty associated with over contribution affects the behavior of groups, thus contributions should be greater when the penalty is lower. For our three treatments, then, we have

> Conjecture 2: Groups in the Utilization Rebate treatment will have higher levels of contributions than groups in the Proportional Rebate treatment, who will have similarly higher contributions than groups in the No Rebate treatment.

Another informal conjecture suggests that the frequency of equilibria we observe will depend on the penalties for deviating from those equilibria. Since the No Rebate policy creates the largest penalty for over contribution, we might expect subjects in this treatment to focus the

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most on the efficient Nash equilibrium contribution level. The Utilization Rebate policy with the smallest penalty for over contribution should generate the weakest focus on the efficient Nash equilibrium contribution level. Conjecture 3 captures this notion that as the penalty from over contribution rises, so does the proportion of equilibria played.

> Conjecture 3: Groups in the No Rebate treatment are more likely to play an efficient Nash equilibrium than groups in the Proportional Rebate treatment. Groups in the Proportional Rebate treatment are more likely to play an efficient Nash equilibrium than groups in the Utilization Rebate treatment.

B. Individual Contributions

Although the provision point game examined here has a continuum of Nash equilibria, it also has a unique symmetric equilibrium in which each of the five members of the group allocates 25 tokens to the group account. This equilibrium may serve as a focal point for the players, especially in treatments with higher penalties for miscoordination. The No Rebate treatment has the highest penalty, and the Utilization Rebate treatment the lowest. Thus we would expect a higher proportion of players playing *their part of* the unique symmetric efficient Nash equilibrium in the No Rebate treatment, and a lower proportion in the Utilization Rebate treatment. This intuition is captured in Conjecture 4

> Conjecture 4: The proportion of players playing their part of the unique symmetric efficient Nash equilibrium will be higher in the No Rebate treatment than in the Proportional Rebate treatment and similarly higher in the Proportional Rebate treatment than in the Utilization Rebate treatment.

C. Convergence

Finally, we can look at group data over time. Although economic theory suggests subjects will play the Nash equilibrium, in practice such equilibria are not as much played as they are

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arrived at or converged toward. In this experiment the stage game was repeated 25 times. We might think that subjects use this repetition to coordinate on a particular efficient Nash equilibrium.

Conjecture 5: Group contributions approach the Nash equilibrium outcome of 125 tokens in all three treatments.

The next section presents the results of the experiment and addresses Conjectures 1 through 5.

5. Results and Analysis

Figures 1, 2, and 3 show the total contributions for each period in each session by treatment.

Insert Figures 1, 2 and 3 about here

A. Group Contributions

This subsection provides analysis of group contributions to the public good. Table 1 displays summary statistics for group contribution levels of the three treatments.

Insert Table 1 about here

Clearly, groups do not always arrive at a Nash equilibrium. Nonetheless, the Nash equilibrium prediction does a good job of organizing the data in the Proportional and No Rebate treatments. To show this we run a random effects model using GLS.[10] The dependent variable

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[10]The random effects model corrects for covariance in the error term caused by multiple observations from a single group of subjects. Unless reported otherwise, regressions use two-factor random effects models. The first factor is the group to which the observation belongs, the second factor is the period in which the outcome was observed. Comparisons are thus between treatments controlling for changes in behavior over time.

was total group contributions, and the independent variables were dummies for the treatments (NR = regression constant, PR and UR). The regression output is presented in Table 2.

Insert Table 2 about here

We can use these results to test the hypothesis that average contributions in each of the three treatments equal 125. That hypothesis cannot be rejected for either the Proportional or No Rebate treatments ($F(1,9) = 0.00$, Prob > F = .9314; $F(1,9) = .10$, Prob > F = .7617 respectively). However, it can be rejected for the Utilization Rebate treatment ($F(1,9) = 60.98$, Prob > F = .0000).[11] Support for Conjecture 1 (that groups play Nash equilibrium) is mixed. Clearly it is not the case that in each round of the game subjects coordinate on a Nash equilibrium. But in the Proportional and No Rebate treatments, average contributions are not statistically distinguishable from the Nash equilibrium prediction. These results are summarized in Observation 1.

Observation 1: Average contributions in the Proportional and No Rebate treatments are not statistically distinguishable from the Nash equilibrium contributions of 125 tokens. However, contributions in the Utilization Rebate treatment are significantly higher than the equilibrium contribution of 125 tokens (mixed support for Conjecture 1).

The results from the regression reported in Table 2 can also be used to test the competing Conjecture 2, that higher contributions will be observed in treatments with lower penalties for over contribution. That conjecture cannot be supported for the comparison between the Proportional and No Rebate treatments, where contributions are not distinguishable from one

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[11]Two other statistical tests of these hypotheses lead to the same conclusion. Both involve finding each group's average contribution over 25 periods. Thus each treatment is summarized into four independent observations. A t-test with three degrees of freedom on these four observations fails to reject the hypotheses that average contributions = 125 in the Proportional and No Rebate treatments ($t = -.10$, Pr > |t| = .9277; $t = -2.07$, Pr > |t| = .1305 respectively). However, we can reject the hypothesis that average contributions = 125 in the Utilization Rebate treatment ($t = 5.30$, Pr > |t| = .0131). Using the same four observations per treatment, a Wilcoxon signed-rank test produces qualitatively similar results.

another (the PR coefficient is not significantly different from zero). However, contributions in the Utilization Rebate treatment are significantly higher than those in the other two conditions. For comparison with the No Rebate treatment it is enough to observe that the UR coefficient is significantly different from zero. A separate comparison with the Proportional Rebate treatment suggests significant difference as well ($F(1,9) = 31.19$, Prob $> F = .0003$).[12] This mixed support is summarized in Observation 2.

> Observation 2: Average contributions in the Proportional and No Rebate treatments are not statistically distinguishable from each other. However, average contributions in the Utilization Rebate treatment are significantly higher than in either of the other two (mixed support for Conjecture 2).

One particularly salient feature of the data are the different variances of contributions in the three treatments. Two sorts of variance are of interest in this analysis. The first is the extent to which groups within a treatment differ from each other. Figures 1-3 suggest that the four groups in the Utilization Rebate treatment differ more from each other than the four groups in the No Rebate treatment in any given period. Another random effects model using GLS is run to test the significance of this sort of variance.

The dependent variable is constructed to capture the spread of the groups. For each treatment in each period, we calculate the average contribution of the four groups. Each group's squared distance from this average is then calculated and used as the dependent variable. The independent variables were the same dummies from the previous regression (NR = regression constant, PR and UR). Regression output is presented in Table 3.

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[12]If each group's contributions are averaged over time, producing four independent observations per treatment, a two-tailed Mann-Whitney U test cannot distinguish between contributions in the Proportional and No Rebate treatments ($U = 6$, $p = .686$). However, the same test rejects the null hypothesis of similarity between the Utilization and Proportional Rebate treatments ($U = 0$, $p = .028$) and between the Utilization and No Rebate treatments ($U = 0$, $p = .028$).

These results support the hypothesis that the variances in the three treatments are ordered by the penalty for over contribution. The No Rebate treatment clearly has the least variance of the three treatments. The Proportional Rebate dummy is (almost) significantly different from zero at the 5% level, suggesting that the variance in that treatment is higher than the variance in the No Rebate treatment. The Utilization Rebate dummy is significantly different from zero, and a comparison of the Proportional and Utilization Rebate coefficients suggest the variances in those two treatments differ as well $(F(1,9) = 40.99, \text{Prob} > F = .0001)$.

The second sort of variance which may be of interest is the variance of a group's contributions over time. For each group in each treatment we calculate the variance of their contributions over 25 periods. With four independent data points in each treatment, a Mann-Whitney U test provides pairwise comparisons. Given the previous results, a one-tailed test was used. Groups move more in the Proportional than in the No Rebate treatments $(U = 2, p = .057)$, and more in the Utilization than in the Proportional Rebate treatments $(U = 0, p = .014)$.

Both these measures of variance suggest Observation 3.

Observation 3: As the penalty for over contribution drops through the three treatments, the variance in contribution level rises.

This result was not hypothesized, but is consistent with some post-hoc analysis of adaptive learning theories.[13] We reserve a full discussion of learning theories in this game to another paper.

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[13]The intuition here rests on the negatively-sloped best response function. If others in your group are high contributors your best response is to contribute low. In treatments where the penalty for over contribution is low (like the Utilization Rebate treatment), individuals have an incentive to contribute high. The natural response in later rounds is to contribute very few tokens, leading to wide swings in contribution behavior. For example, simulations run using the Roth and Erev (1995) adaptive learning model on these three payoff functions involve similarly-ordered variances in the three treatments, under a variety of parameter values (parameter values and details of the adaptive learning model can be found in Erev and Roth (1995)).

B. *Proportions of Success and Nash Equilibria*

This subsection provides an analysis of the frequencies of successful provisions of the public good and Nash equilibria played in each of the three treatments. The provision point is met and the public good funded slightly more than half the time in all three treatments. These proportions of successful provision are not significantly different from each other. To show this we calculate the proportions of successful provisions of each group over 25 periods. A two-tailed Mann-Whitney U test compares the four independent data points in each treatment, and finds no significant differences between any pairwise comparison (NR vs PR: $U = 6.5$, $p = .786$; PR vs UR: $U = 5$, $p = .468$; NR vs UR: $U = 6.5$, $p = .786$).

> Observation 4: Although subjects achieve the provision point only slightly more than half the time, the frequency with which the public good is provided does not vary with the rebate mechanism.

However, the proportion of equilibrium outcomes observed (that is, the proportion of times the public good is exactly provided) does differ between the treatments. That proportion is significantly higher in the No Rebate treatment than in either of the other two. A similar construction as described above provides four independent observations per treatment of the proportion of times the public good is exactly funded. The same two-tailed Mann-Whitney U test finds an almost significant difference between those proportions in the Proportional and No Rebate treatment ($U = 1$, $p = .058$) and a significant difference between the Utilization and No Rebate treatment ($U = 0$, $p = .028$). No difference is found between the proportions of Nash equilibria played between the Proportional and Utilization Rebate treatments ($U = 5.5$, $p = .586$). This result provides partial support for Conjecture 3, which suggested that treatments with higher penalties for over contribution will have a higher incidence of Nash equilibrium play.

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Observation 5: The proportion of equilibrium outcomes are significantly higher in the No Rebate treatment than in either of the other two (mixed support for Conjecture 3).

This observation also addresses the differences between previous experimental results of Bagnoli and McKee and Isaac, *et al.* Bagnoli and McKee used a no-rebate structure in their experiment and find strong support for the Nash equilibrium (for group sizes of five, 54% of their observations are Nash equilibria). In contrast, Isaac *et al.* use a utilization rebate structure, and find only 3% Nash equilibrium play in their medium threshold treatment.

C. *Summary of Group Data*

Using data at the group level there are a number of important conclusions we can draw. Contributions are significantly higher under the Utilization Rebate rule than under either of the other two rules (mixed support for Conjecture 2). The variance of contributions is significantly different under all three rules; highest in the Utilization Rebate treatment (with the lowest penalties for over contribution) and lowest in the No Rebate treatment (with the highest penalties). Subjects clearly do not play a Nash equilibrium in each round of the three treatments, but on average group contributions cannot be distinguished from Nash equilibrium play in either the No Rebate or Proportional Rebate treatments (mixed support for Conjecture 1). Although there are no differences in the proportion of successes between the three treatments, we observe significantly more Nash equilibrium play in the No Rebate treatment than in the other two (Conjecture 3). This result is consistent with the high levels of equilibrium play observed by Bagnoli and McKee (who used no rebates) and the low levels observed by Isaac *et al.* (who used a utilization rebate).

D. *Individual Contribution Data*

The discussion above refers to total group contribution levels in each period and does not address how contributions are distributed among group members. Conjecture 4 suggests that individual contributions will be differentially consistent with a symmetric cost-sharing rule in

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different treatments. The symmetric equilibrium can be described as exhibiting the property of fairness if individuals focus on ability or willingness to pay as a criteria. Given that endowments and valuations are homogeneous, and that this is common information, the symmetric cost-sharing rule is transparent and provides a potentially strong focal point. Under a symmetric cost-sharing rule, each of the five individuals contributes 25 tokens; an equal share of the cost threshold.

The overall proportions of symmetric equilibrium contributions in the No Rebate treatment is .508, in the Proportional Rebate treatment is .284 and in the Utilization Rebate treatment is .074. To show the statistical differences between these proportions, we calculate for each individual in the experiment the proportion of times they played their part of the symmetric equilibrium. With 20 observations in each treatment (one for each individual) we use a one-tailed Mann-Whitney U test to test Conjecture 4. The proportion of individuals playing the symmetric equilibrium strategy is significantly lower in the Proportional than in the No Rebate treatment (U = 127, p ≤ .025) and that proportion is significantly lower in the Utilization than in the Proportional Rebate treatment (U = 132, p ≤ .05).

> Observation 6: The proportion of subjects playing their part of the symmetric equilibrium is highest in the No Rebate treatment and lowest in the Utilization Rebate treatment, with the Proportional Rebate treatment falling in between (support for Conjecture 4).

This observation provides strong support for Conjecture 4, which completely ordered the three treatments as to the proportion of individual Nash equilibrium play expected as a function of the penalty from over contribution in each treatment.

E. Convergence

Finally, we examine whether groups converged toward an efficient Nash equilibrium during the experimental session (Conjecture 5). First we calculate the squared distance between the group contribution and the equilibrium outcome of 125 tokens in each period for each group.

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Diff125 becomes the dependent variable in three one-way random effects GLS regressions (one for each treatment). Independent variables are period and period squared. Table 4 presents the results of these regressions.[14]

Insert Table 4 about here

If groups are converging toward 125 tokens we should observe a significant and negative effect of period on squared deviation from equilibrium outcomes. A significant coefficient (of any sign) on period squared suggests that the convergence is nonlinear. In all three treatments, both these coefficients are significantly different than zero. The negative coefficients on period suggest groups converge toward the group contribution of 125 over the course of the game. The positive coefficients on period squared suggests the convergence slows over the course of the game. This result supports Conjecture 5.

Observation 7: In all three treatments, groups converge toward 125 (support for Conjecture 5).

6. Summary and Conclusions

This research explores the rebate feature of voluntary public goods provision. The investigation concludes that selection of the rebate policy has a significant impact on the frequency of equilibrium play, individual behavior and total contribution levels.

We find contributions to be significantly higher when excess contributions are utilized (Utilization Rebate treatment) than when they are rebated to contributors proportionally (Proportional Rebate treatment) or wasted (No Rebate treatment) (Observation 2). In the latter two treatments average contribution levels cannot be distinguished from the Nash equilibrium contribution level, while contributions are significantly higher than Nash levels in the Utilization

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[14]Clearly when describing behavior over time, period number cannot be used in a random effects model. These regressions only provide random effects for groups, not for period number.

Rebate treatment (Observation 1). Even though average contributions in the Utilization Rebate treatment are higher, the proportion of times the public good is actually funded is not significantly different between the three treatments (Observation 4).

This result is driven by the significantly different variances between the three rebate mechanisms, highest when the penalty for over contribution is lowest in Utilization Rebate, and lowest when the penalty for over contribution is highest in No Rebate (Observation 3). These variances reflect the underlying penalties from over contribution in each of the three treatments.

The proportion of equilibria played was significantly higher in the No Rebate treatment than in either of the other two treatments (Observation 5). This result helps organize the conflicting experimental results of Bagnoli and McKee (who observed 54% Nash equilibrium play under a No Rebate rule) and Isaac *et al.* (who observed 3% Nash equilibrium play under a Utilization Rebate rule). Finally, contributions converge toward the Nash equilibrium outcome in all three treatments (Observation 7).

The results of this experiment suggest that rebate features do not influence the proportion of successful provisions of threshold public goods. However, if the objective is to maximize contribution levels, a Utilization Rebate mechanism can be more productive. On the other hand, if the objective is to minimize the variance of contributions or increase the frequency of equitable cost-sharing, a No Rebate procedure is preferable.

These results provide information on the importance of the rebate feature. We hope it will aid economists in furthering their understanding of decentralized public goods mechanisms, as well as help policy makers in selecting policy implementations of provision point mechanisms.

Figure 2:
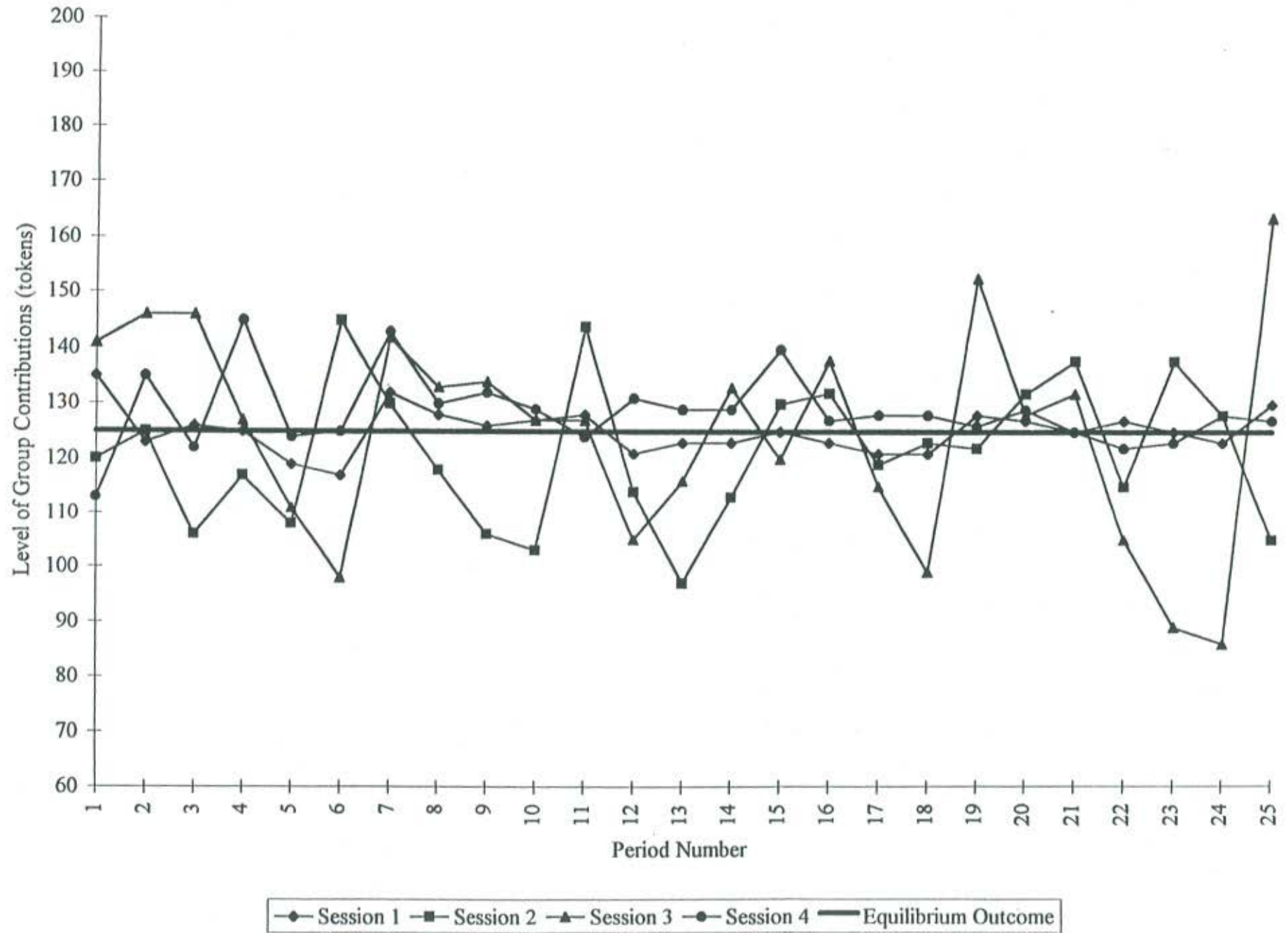Proportional Rebate Treatment Group Contributions

Figure 3:
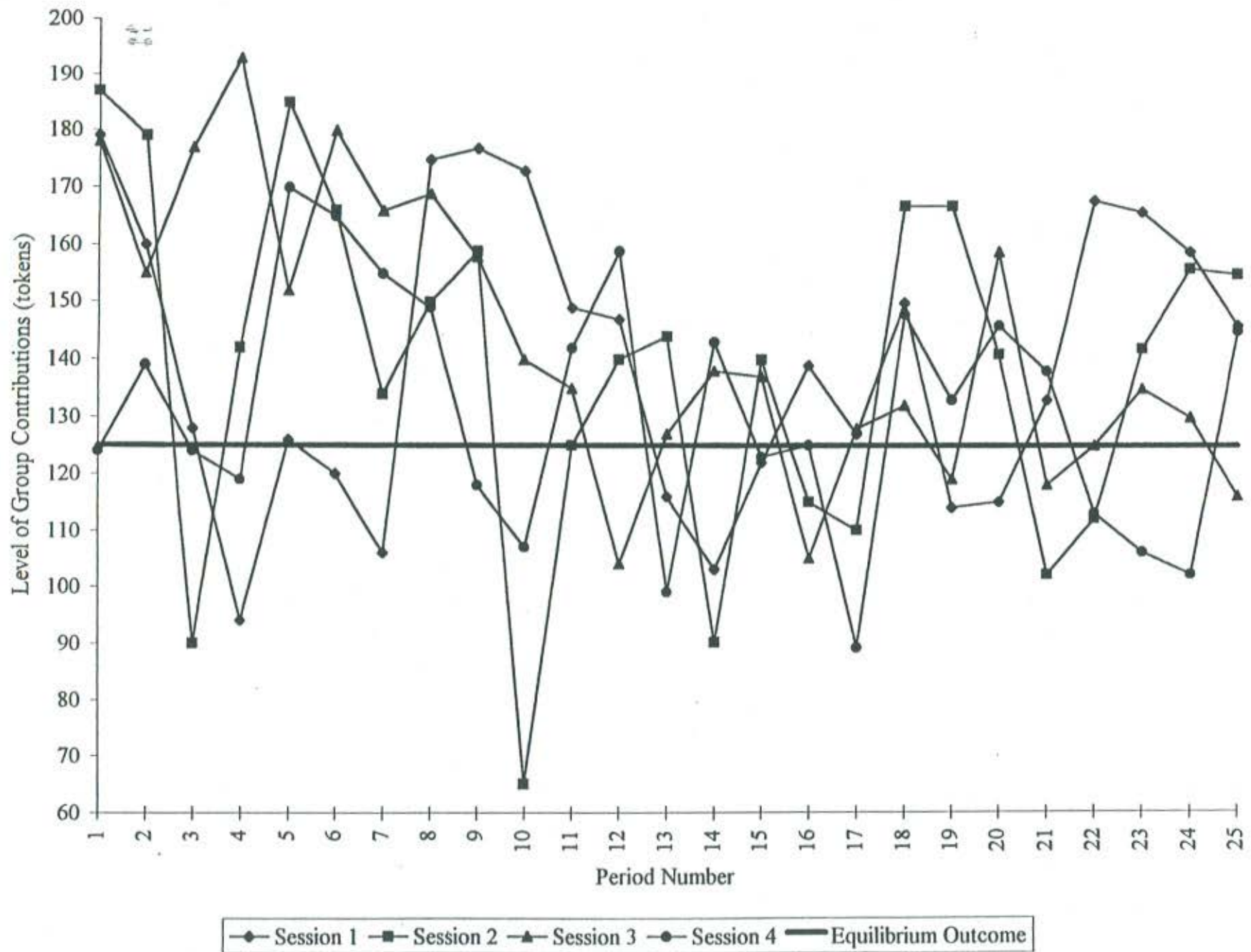Utilization Rebate Treatment Group Contributions

Table 1
Descriptive Statistics (Group Decisions)

	No Rebate	Proportional Rebate	Utilization Rebate
Mean Contributions (St Dev)	124.47 (4.02)	124.85 (12.67)	138.24 (25.87)
Proportion of Successes	0.63	0.59	0.69
Proportion of Equilibria	0.34	0.07	0.03

Table 2
Two-Factor Random Effects GLS Regression (Contributions)

Number of observations			300	
n = number of groups			12	
T= number of periods			25	
R-squared overall =			0.1298	

Group Cont	Coefficient	Std. Err.	t	P>|t|
PR	0.3799992	2.397729	0.158	0.878
UR	13.77	2.397729	5.743	0.000
constant	124.47	1.69545	73.414	0.000

Table 3
Two-Factor Random Effects GLS Regression (Squared Distance)

	Number of observations		300	
	n = number of groups		12	
	T= number of periods		25	
	R-squared overall =		0.1865	

Sq. Dist.	Coefficient	Std. Err.	t	P>|t|
PR	112.455	51.309	2.192	0.056
UR	440.968	51.309	8.594	0.000
constant	9.953	36.281	0.247	0.790

Table 4
One Way Random Effects GLS Regression (Squared Distance 125)

No Rebate

	Number of observations		100	
	n = number of groups		4	
	R-squared overall =		0.2004	

Diff125	Coefficient	Std. Err.	t	P>|t|
period	-8.01	1.72	-4.670	0.000
period2	0.24	0.06	3.762	0.000
constant	67.21	19.68	3.415	0.001

Proportional Rebate

	Number of observations		100	
	n = number of groups		4	
	R-squared overall		0.2613	

Diff125	Coefficient	Std. Err.	t	P>|t|
period	-176.29	52.42	-3.363	0.001
period2	4.58	1.96	2.342	0.019
constant	2113.40	362.64	5.828	0.000

Utilization Rebate

	Number of observations		100	
	n = number of groups		4	
	R-squared overall		0.0625	

Diff125	Coefficient	Std. Err.	t	P>|t|
period	-30.68	14.45	-2.123	0.034
period2	1.37	0.54	2.538	0.011
constant	225.25	162.96	1.382	0.117

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