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CAN THE PRIVATE PROVISION OF PUBLIC GOODS BE EFFICIENT? — SOME EXPERIMENTAL EVIDENCE *

by

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1. Introduction

The received theory on public goods asserts that private provision of them is at best inefficient and at worst virtually non–existent due to the severity of the free rider problem. This assertion has received additional theoretical[1] and experimental[2] support recently. However, in a recent paper, Bagnoli and Lipman [1986] have studied a simple contribution game in which all of the proper equilibria in pure strategies are Pareto efficient and all strongly, individually rational Pareto efficient outcomes can be supported as a proper equilibrium in pure strategies. In other words, in this game, the free rider problem does not appear to be severe enough to keep the citizens from privately providing the efficient level of the public good. Our purpose in this paper is to report on some experimental evidence that supports the conclusion reached in Bagnoli and Lipman (hereafter B&L). That is, our results suggest that if private provision is adequately modeled by the B&L's game, then private provision of public goods is predominantly efficient. We should note that there is supportive anecdotal evidence. In 1980 and 1985 the New Democratic Party (NDP) of Manitoba. Canada sent letters to its larger contributors explaining the need for additional funds to mount the coming election campaigns. The letters explained the need for a certain amount of money, $200.000.00 in 1980 and $250,000.00 in 1985. The letters included an explanation of how the money was to be used and promised to **refund** the contributions if less than the required amount was contributed. We learned that in 1985, total contributions were $251,300.00 or about $\frac{1}{2}$% more than the required total.[3]

As B&L argued, one interpretation of their result is that they have produced a "fairly natural" game that resolves an apparent conflict between the recent theoretical work on private provision and the older mechanism design literature. In the literature on mechanism design, it was shown that there exist mechanisms that implement many different social choice correspondences each of which require the selection of a Pareto efficient outcome.[4] Unfortunately, it appears that this work was understood to have required a social planner to implement and mediate the game. This may explain why the recent theoretical work, cited above, has focused on the study of the

[1] See, for example, Palfrey and Rosenthal [1984, 1985], Bergstrom, Blume and Varian [1986], Andreoni [1985] and Cornes and Sandler [1985a, b].

[2] See, Schneider and Pommerehne [1982], Marwell and Ames [1981], Kim and Walker [1984], Isaac, Walker and Thomas [1984], Isaac, McCue and Plott [1985], Andreoni [1986], and Harrison and Hirshleifer [1986].

[3] We wish to thank Ron Cavalucci for providing us with this information.

[4] See the recent survey by Groves and Ledyard [1985] for details and references.

properties of "fairly natural" games that might describe the process of private provision in the absence of a social planner. Thus, since Bagnoli and Lipman have studied a game that could well describe the process of private provision in the absence of a social planner, they may have studied one of the games that links the two literatures together.

However, their results depend on the application of a refinement, properness, to the definition of an equilibrium. Consequently, it becomes very important to determine whether the restriction to proper equilibria in pure strategies is reasonable or not. However, there is, another reason for undertaking the experiments. They will provide an alternative approach to the study of the severity of the free rider problem. Studying this issue has been one of the major focuses of much of the experimental work on private provision of public goods. This work was triggered by the casual observation that private provision of public goods is not virtually non–existent which suggests that the free rider problem might not be as severe as received theory seemed to suggest. Examples of naturally occurring instances of high levels of private provision of public goods include public radio and television, many charities and many local public goods such as gardens, playgrounds, parks, museums, and concerts. Additional examples include the provision of industry lobby groups, other lobby groups supported by private contributions, and the setting and enforcing of private industry standards for safety, quality, etc. One obvious explanation is that such behavior was the result of other motives, for example, altruism. Another obvious explanation is that received theory had been interpreted over zealously. That is, the free rider problem is severe enough to cause private provision to be inefficient but not severe enough to cause it to be approximately zero. This version of the free rider problem has come to be known as the weak form of free riding.

This controversy led to an experimental investigation of free riding.[5] The motivating idea was that a laboratory setting would permit the experimenter to isolate the effects of any non-pecuniary motives which had been suggested as a possible explanation for the observations mentioned in the previous paragraph. Unfortunately, their results were mixed. Some appeared to find no support for the strong version of the free rider hypothesis while others appear to have found some support for the weak version. Basically, most found that a positive but inefficient level of provision was obtained.

Isaac, McCue and Plott [1985] argued that the results might have been mixed due to flaws in

[5] See the papers cited in footnote 2.

the experimental design. In particular, they argued that one might need to provide the participants with time to learn the game. If that were true then the one–shot experiments which, by definition, do not give the participants time to learn the game, might be flawed. However, correcting for this and other flaws does not appear to alter the general conclusion that the experimenters find some support for the weak version of the free rider problem but none for the strong version.[6]

One important aspect of the experimental design which IMP did not consider is common to all but one of the experiments with which we are familiar.[7] Every experimenter modeled the private provision of a public good as a prisoners' dilemma game. The apparent explanation for this is that the traditional view of the problem of private provision is that free riding is an important feature that leads to inefficient provision. Thus, the experimenters were led to adopt a standard game whose equilibrium is inefficient. Unfortunately, the prisoners' dilemma game has an additional feature: players have a dominant strategy, not cooperating. The theoretical literature had already moved away from this representation recognizing it as an inadequate model. Basically, they realized that an individual's optimal contribution for the private provision of the public good would depend on the contributions of the others. The idea is that if the individual's willingness–to–pay for the next little bit of the public good exceeds the cost then this individual's optimal choice is to contribute something. The obvious question is can this dependence on the choices of others ever happen. If it cannot then the prisoners' dilemma game is an adequate representation of the problem. However, it is clear that it does occur but that its importance depends on the actual contributions of the other members of the society.[8]

The following example is not meant to explain what the contributions of the individuals will be but simply to illustrate that their optimal contribution should depend on the contributions of the others. Having done this, we will have demonstrated that the use of the prisoners' dilemma game is inappropriate in modelling private provision. In our example, let there be n people in the society and suppose that each of them is willing to pay x for the first unit of the public good. If the individual that we focus on, say person 1, believes that the contributions of each of the others

[6] We find it interesting that no one has proposed one of the most likely explanations for these results. The experimenter can only induce valuations. He or she cannot guarantee to each player that the induced valuation is truly the other player's utility. That is, the experimenter cannot ensure that the players are playing a game of complete information. It is well known that equilibria in the prisoners' dilemma with incomplete information do not require that players choose not to cooperate. Obviously, there is no way to avoid this problem as it is inherent in the methodology of experimental economics but it should be remembered that it exists and may well explain what are otherwise anomalous results.

[7] The exception is a recent piece by Harrison and Hirshleifer which we will mention briefly below.

[8] We have recently learned that a similar argument has been made by Frohlich and Oppenheimer [1970] and Frohlich, Hunt, Oppenheimer and Wagner [1975].

will be σ_i then this individual's best action will depend on his or her belief about the sum of the others' contributions. Let $\sigma = \sum_{i=2}^{n} \sigma_i$. If c is the cost of the first unit, and if $c - \sigma$ is positive and greater than this individual's valuation, x, then this individual's optimal contribution is zero. However, if $c - \sigma$ is less than x, then the optimal contribution is positive. To see this simply note that $x > c - \sigma > 0$ implies that $x + \sigma > c$. Therefore, there is a contribution, σ_1 which is less than x such that $\sigma_1 + \sigma = c$. If this contribution is made, then person 1's net benefit is positive, $x - \sigma_1$, which exceeds the net benefit of contributing nothing. The net benefit of contributing nothing is 0 because the individual gave nothing but no units of the public good were provided either. Thus, we must conclude that the prisoners' dilemma game is an inadequate representation of private provision of public goods.

Our work is most closely related to a recent paper by Harrison and Hirshleifer. Their work is an attempt to study, in an experimental setting, some of the conclusions Hirshleifer reached in an extremely interesting paper he wrote in 1983. In it, he considered different types of public goods that he identified by their production technology. Most relevant to this discussion, only one of the types is supposed to be adequately represented by a prisoners' dilemma game. Hirshleifer suggested that received theory would apply differently to the different types of public goods. The Harrison and Hirshleifer paper seeks to study Hirshleifer's conclusions in an experimental setting. Unfortunately, there are may be a potential difficulty with their test. Hirshleifer studied games of complete information, that is, games in which all of the relevant data is known to every player. This includes the value the other players' place on the public good. However, their experimental design forces the players to play a game of incomplete information. So, even though there may be some question as to whether their work can be taken as an experimental test of Hirshleifer's original work, it remains an interesting and important extension to our understanding of private provision because of its contribution to our understanding of private provision in non-prisoners' dilemma games.

We can summarize by saying that our research pursues three objectives. The first is to determine whether the restriction to proper equilibria is appropriate. The second is to provide additional information concerning the severity of the free rider problem in the context of one model of private provision of public goods. Our third objective follows from the arguments just presented. The experimental work on public goods has not focused on a sufficiently wide set of underlying games and one of our contributions will be to report on the results based on the game studied by Bagnoli and Lipman.

Our results suggest that the restriction to properness is appropriate. For the last five periods, we found the participants' contributions yielded the efficient level of provision 100% of the time. We report the last five periods here in response to the concerns raised by Isaac, McCue and Plott, who argued that the participants needed time to learn the game. Obviously, our results show that the free rider problem is not severe enough to prevent the private provision of public goods in this game. Clearly, this suggests that since the free rider problem is more severe in other games,[9] it is important to begin the study of the choice of game through which the public good is privately provided. This provides additional support for the position that a wider set of underlying games needs to be studied if we are to get a better understanding of private provision.

One striking result from our experiments is that the efficient outcome is achieved even when the participants are very different. In some of our sessions, the individuals had equal valuations but different incomes while in others, they had equal incomes but different valuations. In fact, some of the differences were quite large. In spite of this, these groups were as capable of efficient provision as the group that contained participants with identical incomes *and* valuations. What is perhaps surprising is that in the sessions in which the participants differed, some were identical but did not choose the same levels of contributions. That is, there is clear evidence of strategic play during the sessions.

In the next section we provide a relatively brief description of the game that underlies our experiments. In section 3 we describe the experimental design. Section 4 contains the results and our conclusions are presented in Section 5.

[9] We are alluding to the other recent theoretical work cited earlier.

2. The Model

The complete description of the game on which our experiments are based may be found in Bagnoli and Lipman [1986]. We present a brief summary here. B&L study a contribution game in which the agents choose how much money to contribute for the public good. They studied two kinds of decisions, only one of which will concern us in this paper. The decision considered here is whether or not the public good is provided.[10] That is, the citizens have a simple decision: to provide the public good or not. Our description of the game will be cast as a decision to provide a streetlight or not.[11] The streetlight will illuminate the property of several persons and, as such, it is a public good. B&L show that, under very weak conditions on the individuals' utility functions, the efficient decision will result. In this paper, we will restrict attention to the case in which the efficient decision is to provide the streetlight. Thus, B&L's theorem implies that the equilibrium has the streetlight provided from the voluntary contributions of the individual agents.

More formally, consider an economy with I agents indexed by $i = 1, 2, \ldots, I$. These agents must choose a decision d from the set $\{0, 1\}$. One interprets 0 as the decision not to build the streetlight and 1 as the decision to build. Each agent benefits from the presence of the streetlight, though agents may not benefit equally. More precisely, assume the utility function of the i^{th} agent is $u_i(d, w_i)$ where w_i is the i^{th} agent's wealth and assume that

$$u_i(1, w_i) > u_i(0, w_i) \quad \forall w_i, i = 1, 2, \ldots, I.$$

Also assume that for all i, u_i is continuous and strictly increasing in w_i. Without loss of generality, adopt the normalization $u_i(0, w_i) = 0$ for each i. Define the valuation of agent i, v_i implicitly by

$$u_i(1, w_i - v_i) = 0 \ (\equiv u_i(0, w_i)).$$

The last assumption made is that $w_i > v_i$ for all i—that is, $u_i(1, 0) < 0$. This assumption is made so

[10] B&L also studied the situation in which the decision is not only whether to provide the public good but in what quantity. We intend to study this version experimentally in a future paper.

[11] Obviously, casting our discussion in this framework does not limit the analysis to this framework. In particular, any public good whose provision may be cast as a zero–one decision immediately fits this framework. If it cannot, then it can be cast in the framework of the multiple streetlight problem also studied by B&L. In that version, one imagines providing the first bit of the public good, the second bit, and so on. Alternatively, one may employ this version to study the "size" of the streetlight to be provided. Under somewhat more restrictive assumptions on the utility functions, B&L have proven the same theorem for the more than one unit case. We intend to test this result, experimentally, in future work

that one need not consider what happens when some agents would like to contribute more than their wealth. Only games of complete information are considered so that all of the above information (including each utility function) is common knowledge.

The cost of providing the streetlight is $c > 0$. which is also common knowledge. Bagnoli and Lipman suggest that a seemingly natural way to consider the problem of how agents get together to jointly provide the streetlight is to suppose that they contribute money toward building it. They study a game in which the streetlight is provided if the contributions add to c or more and any contributions in excess of c are kept. In the event that contributions sum to less than c, the streetlight is not provided and contributions are returned.[12]

Thus, the formal description of the game has each agent's strategy set $S_i = [0, w_i]$. A strategy choice by i is denoted σ_i and is interpreted as this agent's contribution. If $\sum_i \sigma_i \geq c$, then the public good is provided and all contributions are kept. In this event, the payoff to i is $u_i(1, w_i - \sigma_i)$. Otherwise the good is not provided and the payoff to i is $u_i(0, w_i)$ which has been normalized to equal 0. For this simple game B&L prove the following theorem.

> **Theorem 1**: *All proper equilibria in pure strategies have efficient outcomes. Furthermore. any Pareto efficient, strongly individual rational outcome is realized as a proper equilibrium in pure strategies.*

That is, the outcome of the game is Pareto efficient if the outcome corresponds to a proper equilibrium in pure strategies. The proof is provided in Bagnoli and Lipman [1986]. The intuition is quite straightforward. If $\sum_i v_i < c$, then the efficient outcome is to choose $d = 0$. That is, if the sum of the valuations is less than c then it is better not to provide the streetlight. In this case, it is clear that no Nash equilibrium has the sum of the contributions greater than c. This happens because no individual would choose to contribute more than v_i when the sum of the valuations is less than c.

If the sum of the valuations is just equal to c then either decision is Pareto efficient. If the sum of the valuations is greater than c, the case is more complex. First, note that a Nash

[12] Clearly, other institutions are possible. For example, the contributions could be kept even if the good is not to be provided. As B&L point out, such arrangements raise the possibility of insufficient contributions and is therefore an alternative worthy of study.

equilibrium in pure strategies cannot have the contributions add to strictly more than c since any contributor would then prefer a smaller contribution. Hence all proper equilibria in pure strategies certainly have $\sum_i \sigma_i \leq c$. To see that one can eliminate the possibility that contributions are strictly less than c is more difficult and is the heart of the proof of the theorem. Those interested in the proof are referred to the paper. Here, we try to provide a little intuition as to why it is true.

There are many Nash equilibria in the game. As stated earlier, when the efficient decision is $d = 0$, all Nash equilibria have this outcome since each agent will refuse to contribute more than v_i if there is a nonzero probability that such contribution will lead to $d = 1$. However, when the efficient decision is $d = 1$, there are many Nash equilibria, some of which lead to inefficient outcomes. Focusing on the pure strategy equilibria only, the Nash equilibria fall into two groups. First, any vector of contributions satisfying $\sigma_i < v_i$ and $\sum_i \sigma_i = c$ is a strong Nash equilibrium. Hence these equilibria satisfy all of the regularity properties ever proposed for Nash equilibria. Second, any vector of contributions satisfying $c - \sum_{j \neq i} \sigma_j \geq v_i$ is also a Nash equilibrium and has $d = 0$. It is these equilibria that are removed by the restriction to proper equilibria and it is intuitive that they are not robust.

To see this, note that if the agents other than i might "tremble" upward in their contributions, then, so long as i's contribution is less than v_i, i wishes to increase his contribution to increase the probability that he earns a positive payoff.[13] In fact, a small possibility of such trembles is enough to make i strictly prefer a larger contribution.[14]

From the model we can derive a number of testable hypotheses. First, all proper equilibria produce an efficient outcome. Thus, the good will be provided when the sum of the valuations exceeds its cost. Further, the sum of the contributions will be equal to the cost of the good. In the experimental setting we provided that the sum of the valuations was greater than the cost of the good in all cases. Thus we state our first testable hypothesis:

Hypothesis 1: The public good will be provided and the contributions will sum to its cost.

[13] Recall that his utility function has been normalized so that if the streetlight is not built, his payoff is zero

[14] Those familiar with the use of refinements will note that this argument essentially suggests that equilibria with $d = 0$ are not "trembling hand" perfect. This is not quite correct as one can find trembles that will support such a decision. However, these trembles must be to dominated strategies. Thus it is reasonable that the application of properness removes these cases. For details the reader is referred to B&L.

That is, the subjects will attain the equilibrium described in the model. There are two possible ways to falsify this hypothesis. First, the contributions may sum to less than the cost of the good and, as a result, the good would not be provided. Second, the good is provided but the contributions sum to more than the cost of the good. The fact that violations of the predictions can occur both ways is worth keeping in mind when we discuss the empirical results.

Second, individual rationality requires the subjects to bid not more than the value of the public good to them. We may state this explicitly as:

Hypothesis 2: No subject will bid in excess of his valuation in tokens since this is the maximum he may obtain from the provision of the good.

Third, to handle one of the objections leveled by Isacc, McCue and Plott, the game will be played a finite, known number of periods in the experiment and we announced that the subjects would remain in their groups for the duration of the experimental session. The reason is that allowing the game to run for several periods permits the subjects to learn the game. This has both benefits and costs. The benefits are that it may well be important for the players to "learn" the game. If so the repetitions will be valuable in providing a better understanding of their play. The cost is that in a repeated game, especially one with as many stage equilibria as the one employed, there are many subgame equilibria. However, the usual backward induction argument allows us to state our third hypothesis[15]:

Hypothesis 3: A subgame perfect Nash equilibrium is a sequence of single period game equilibria. That is, the sequence of single period Nash equilibria forms a subgame perfect Nash equilibrium in the repeated game.

Fourth, recall that Theorem 1 admitted the possibility of several equilibria with the hypothesized properties. One conjecture is that the equilibrium actually achieved depends on the distribution of income. Such a possibility may arise because of the multiplicity of equilibria in the game. That is, the multiplicity of equilibria will make it more difficult to achieve the equilibrium in these situations as the players strive to end up in an equilibrium in which their contributions

[15] We note here that caution must be employed when analyzing the data to ensure that this is the subgame perfect equilibrium played. In fact, we will show that there are no "end game effects which suggests that this potential problem may not have arisen.

are smaller. Loosely speaking, the idea is that the players may attempt to strategically manipulate their contributions in order to affect the equilibrium they eventually settle down to. If this occurs, it will manifest itself as fluctuations in the level of contributions from period to period as the agents, in essence, attempt to solve the distribution of surplus associated with the provision of a public good as well as the provision game. To evaluate this possibility we introduced skewed income and valuation distributions in the experimental sessions. We state the relevant hypothesis as[16]:

> **Hypothesis 4**: For more skewed income and valuation distributions it will be harder for the subjects to achieve an equilibrium.

Fifth, Theorem 1 holds regardless of the number of agents in the economy. That is, the theorem is true regardless of the number of players in the game.[17] As a practical matter, most would believe that the free rider problem becomes more severe as the size of the group rises. That is, a larger group may be less likely to attain the equilibrium than a smaller one. Accordingly, we have conducted the experiment for groups of five persons and of ten persons. We state the relevant hypothesis as:

> **Hypothesis 5**: Group size has no impact on the ability of the group to reach the equilibrium. Pareto efficient level of contributions.

[16] Again, caution will be necessary in drawing conclusions here. We are simply providing a standard story for why certain equilibria may be focal and conjecturing that the less obvious is the focal equilibria, the less likely the players are to achieve one of the proper equilibria.

[17] This may, at first, seem troubling because there is a well known intuition that suggests that it is false. The intuition goes as follows: as the number of players gets large, the effect of their choosing not to contribute becomes negligible. Hence, as the number of players gets large, the provision must become inefficient. The theorem proved by B&L shows that this is not correct for this game. In the equilibrium, *all* contributors are pivotal. That is, a change in any contributor's action has a sufficiently important effect on the result so that he has no incentive to change his contribution. In other words the equilibrium resolves the negligibility problem endogenously.

3. The Experimental Design

The experimental environment is designed to implement the features of the game described above and consists of the following conditions. Subjects are assigned to a group in a random fashion. They are informed that the task is to enter a contribution toward the provision of a public good. The public good is described as yielding a specified return to each member of the group. If the good *is* provided, each subject in the group will receive the payoff from provision plus their initial income less their contribution to the public good. Each knows the number of people in their group but not their identities.[18] The subjects are informed of (1) their own income, (2) the incomes of the other members of their group, (3) the cost of the public good, and (4) the payoff to *each* member of the group if the good is provided. Further, the subjects are told that the experimental session will last for a specific number of periods and that they will be in the same group for each period. As well, they know that the level of the required total contribution and the incomes will remain constant over the duration of the experiment. The players are required to choose contributions simultaneously—without knowledge of the choices made by the other members of their group. Consequently, they play a game of complete but not perfect information.

Clearly, the description of the design of our experiment captures the features of the game studied by Bagnoli and Lipman. The subjects have complete information on w_i, v_i, and c. They also know n, the number of members of their group, and that the session will last for a known, finite number of periods with the same parameters in effect for all periods. We induce the valuations in the approved manner [Smith, 1975]. That is, we issue the subjects with tokens which are redeemed by the persons running the experiment when the sessions are completed. We post the exchange rate for the tokens prior to the start of the sessions and maintain it throughout the session. Finally the subjects are informed of the aggregate level of contributions for their group at the end of each stage or period.

Our subjects were recruited from undergraduate students at the University of Michigan and the University of Windsor. The instructions were distributed and read aloud. A copy is provided in the Appendix.

[18] This is done so that there is no possibility of pre-play communication and to ensure that they truly choose without knowing the choices of the other members of their group.

For each period the subjects received an "information slip" like the one provided in the Appendix (or a modified version for the sessions where the subjects were assigned different valuations). The incomes, valuations, and group sizes were entered by the experimenters and the subjects were required to enter their contribution in the space provided.

Questions were answered and the subjects tested to be "certain" they understood the instructions. The subjects had been arranged so that they were unable to learn the identities of the other members of their group and they were provided with the information slips for all periods. The experiment commenced and the subjects were requested to enter their contribution to the public good for the first period.

Once all of the contributions had been entered, the slips were collected by the persons running the experiment and the contributions were totaled. Then the total contributions for each group were written on the board. This ended the first period. The contributions for the next period were then solicited and the process repeated for all periods.

As we discussed in connection with Hypothesis 4 we wished to examine the effects of skewed income and valuation distributions on the provision of the good. Thus we introduced this as an experimental treatment. To repeat, the incomes and valuations of the individual subjects remained constant throughout the session. As with all of the other data for our experiments, this information appears in the Appendix in the tables labeled "Incomes and Valuations".

For each of these five-person groups cost of the public good, referred to as the threshold contribution level, was 12.5 tokens. If the public good was provided, then the additional bundle of tokens was set at 25 tokens. That is, the increase in social welfare if the public good is provided is 12.5 tokens (25 - 12.5).

Theorem 1 holds regardless of the number of persons in the group contributing to the provision of the public good. However we felt that it was important to test this result. We have done this by forming two groups with ten persons each. These groups were included in a session with several groups of five persons. The valuations were constant across the members of the groups (five tokens) and we report their incomes in a table in the Appendix. For the ten person groups the threshold contribution level was set at 25 tokens and the bundle of additional tokens was set at 50.

4. Experimental Results

We ran seven sessions with a group size of five and two sessions with a group size of ten. In response to the criticism of the previous experimental work by Isaac, McCue and Plott, we chose to have the participants make choices in each of fourteen periods.[19] The exogenous information which was known to each member of a group—the number of people in the group, their incomes, and their valuations—are reported in tables in the Appendix.[20]

In addition, all of the raw data, the participants' contributions, are reported in tables 2.11–2.21. We report the raw results for two reasons. First, we feel that summary statistics may not convey enough information and second, the test of the second hypothesis requires that we check each individual's contribution in each period. We also provide two summaries of our data. Each is designed to aid in the test of the other hypotheses. In tables 1A and 1B we summarize the raw data by computing total contributions for each group, for each period. This will provide the clearest test of hypothesis 1.

Tables 3 and 4 provide an alternative viewpoint for testing hypotheses 3–5. They are based on the fact that we have induced the valuations of the subjects. Consequently, we may compute the social welfare for each of the groups. The theoretical welfare maximum is defined to be the sum of the valuations of the members of the group *plus* their incomes *minus* the sum of the contributions at the theoretical equilibrium.[21] When the good is provided, actual social welfare is computed as the sum of the valuations *plus* the sum of the incomes *minus* the actual contributions. If the good is not provided, social welfare is simply the sum of the incomes because contributions are return in this case.

The most striking result that we have to report is that in the overwhelming majority of the cases, the collective good was voluntarily provided. The evidence thus far offers tentative support

19 The number of periods was announced prior to the start of the session.

20 All tables can be found in the Appendix.

21 Recall that the parameters of the experiment are such that it is efficient to have the good provided in each case.

for Hypothesis 1 (the good is provided in the majority of the cases). Taking all fourteen periods, the contributions sum to 12.5 tokens or more in 85 of the 98 possible cases.

The theory predicts that all of the proper equilibria induce the efficient outcome. In our experiments, that means that the sum of the participants' contributions should be 12.5 tokens. If the level is above this then all subjects will prefer a lower level of contribution. If we take 12.5 tokens to be the equilibrium then we achieve this in only 53 of the 98 cases. The theory is defined over games of complete information and, while we provided the subjects with all information regarding the incomes and payoffs of the members of their groups (as specified by the theory), the experimental methodology prohibits ensuring complete information. It is possible for the participants to believe that a "fool" or an individual who doesn't purely care about his or her monetary reward is playing. Further, the existence of many equilibria raises the possibility that the subjects may not be able to easily coordinate on a given equilibrium. Thus we enlarge the definition of equilibrium to include aggregate contributions in the range 12.0 to 13.0 tokens.[22]

Under this relaxed definition the subjects have achieved an efficient equilibrium in 75 of the 98 cases. The impact of the behavioral classification of equilibrium is particularly apparent in the groups with rather uneven distributions of income or valuation. Under the strict definition Group 16, for example, attains the Pareto efficient equilibrium only one time. With the more relaxed definition of the equilibrium it achieves the proper equilibrium in nine periods. A similar sort of behavior is apparent in Group 12. In contrast, groups 14 and 17 hit upon an equilibrium vector of contributions quite early and maintained this throughout. The results described in the previous paragraph provide substantial support for Hypothesis 1. The collective good is provided and the contributions sum to the efficient level. Our results are very strong when we focus on the last five periods only (to allow for learning). We have an efficient outcome (contributions sum to 12 to 13 tokens) in all thirty-five cases. This outcome is consistent with the subjects having "learned the game."

Hypothesis 4 seems to receive some support also. The groups with skewed income or valuation distributions appear to have more difficulty attaining the efficient contribution level.

[22] There are many ways to classify the data. We have already noted that the public good is provided in 85 of the 98 cases. That is, contributions were in excess of 12.5 tokens in these 85 cases. Thus, the game exhibits very little free riding. Allowing for some coordination problems and allowing for the fact that we may not have a clear focal equilibrium, defining equilibrium contributions to be any contribution between 12.0 and 13.0 tokens appears to be quite stringent.

However, we cannot overlook the results of Groups 14 and 17. Each, 14 in particular, was able to reach an efficient equilibrium (narrowly defined) very quickly despite the differences in income across subjects. This conclusion needs to be tempered by the fact that, while these groups do not have equal incomes and valuations, the differences are small. In particular, in both cases, only one subject differs from the rest. Focusing on Groups 12, 13, 15 and 16, the groups with significant differences among the subjects, we find that they did, in fact, have significantly more difficulty providing the efficient level of the public good. If one compares the average welfare levels of groups 12, 13, 15 and 16 to group 11, the probability that group 11 has a higher welfare level than the average of the heterogeneous groups is .927. We have excluded groups 14 and 17 from this comparison because, as we mentioned above, they are nearly homogeneous. Thus, we believe that the correct interpretation of our results is that they lend some support to the Tiebout hypothesis but that a definitive conclusion must await additional work on this question.

Social welfare for each five person group is reported for all periods and in aggregate in Table 3. The theoretical maximum for all fourteen periods is 945.0 tokens and is 337.5 for the last five periods only. We can see that Group 14 attained the highest level (the theoretical maximum) of any group. Several other groups had very high levels of social welfare as well. In fact, five of the seven groups had welfare levels in excess of 95% of the theoretical maximum for all fourteen periods taken together. The findings reported in Table 3 lend further support of Hypothesis 1.

We can compare the resulting welfare levels across groups to test Hypothesis 4. The theory does not distinguish on the basis of the distribution of income or valuations. Since the only differences should be attributable to learning we focus on a comparison using all fourteen periods of the sessions. On the basis of a Mann–Whitney test [Conover, 1980, pp 216-228] we can not reject the hypothesis that the behavior in the homogeneous group, Group 11, does not differ from that of the non–homogenous groups (Groups 12 through 17). The probability that Group 11 has higher welfare level over all fourteen periods is only 0.682. Similarly, there does not seem to be any significant regularity between our treatments of non–homogeneity. On the basis of a Mann–Whitney test we find the probability that the groups with skewed incomes (G12, G13, and G14) had higher levels of efficiency than the groups with skewed valuations (G15, G16, and G17) is only 0.853 which is well outside the normal significance levels.

As further confirmation that any differences across groups should be due to learning behavior we may concentrate on the last five periods. We find that five of the seven groups attained the theoretical maximum level of social welfare and a sixth, Group 16, was very close. In general, we can say the subjects had "learned the game" by the last five periods.

Since our structure of incomes and valuations was symmetric we can do a pairwise comparison across the groups between those with skewed incomes and valuations. On the basis of a Wilcoxon test [Conover, 1980] we can reject the null hypothesis that there is a difference by treatment in all three of our cases. When we compare G12 to G15 we obtain a t–statistic of 3.296 for the null hypothesis that G12 has smaller values (efficiency levels) than G15. Thus we reject the null at 99%. For G13 vs. G16 the t–statistic is 1.538 so we reject the null at 94%. For G14 vs G17 we obtain a t–statistic of -3.296 and we cannot reject the null hypothesis (at 99%) that G14 has smaller values than G17.

In Hypothesis 5, we predicted that a larger group will be as efficient in having the collective good provided as the smaller group. However, a larger group may make it more difficult for the subjects to focus on a particular equilibrium vector of contributions. The qualitative results appear to support this conjecture. The larger groups (G20 and G21) provided the collective good in 19 of 28 possible cases. They attained the efficient outcome (24 to 26 tokens) in 17 cases. These levels are lower than the comparable statistics for the five person groups. We may conduct a more rigorous test by comparing the results (welfare levels) of the five- and ten- person groups (see tables 3 and 4 in the Appendix). Scaling the scores for the ten–person groups (G20 and G21) and using a Mann–Whitney test we find that the probability the five–person groups have higher efficiency scores is 0.987.

Our interpretation of this result is that it is more difficult for the larger groups to focus on an equilibrium vector of contributions. By the last five periods, however, both large groups had welfare levels that were better than 95% of the theoretical maximum level. With learning, which apparently takes longer with the large groups, the subjects were approximately as efficient in the larger groups as the smaller groups. Taking the last five periods we find the success rate at achieving a Pareto efficient equilibrium to be eight of ten (80%) which compares favorably with the results for the smaller groups.

The prediction underlying Hypothesis 2 is that all the agents will post contributions which are individually rational. That is, no subject will post a contribution greater than his/her valuation of the collective good although all subjects have incomes in excess of valuations by definition of the game. Recall that we have reported the individual contribution behavior in Tables 2.11–2.21. Instances of irrational behavior (contributions in excess of valuation) are indicated by an asterisk. It is clear that irrational behavior is very infrequent and occurs primarily in the early periods. Of the 490 observations in the five–person groups only 7 are individually irrational. All but one of these occurred during the first two periods and may be attributed to subject confusion with the game. In all subsequent periods the subjects entered contributions which were individually rational. In the ten–person groups we have only 4 of 280 observations where the contributions can be classified as individually irrational. It is clear that Hypothesis 2 is well supported by the results of the experimental sessions.

On the subject of individual behavior we have a very striking example of the strength of the equilibrium presented in the theoretical discussion. In Group 14 the subjects happened to post a Pareto efficient equilibrium vector of contributions in the first period. They maintained this vector for the duration of the session. What is interesting is that the vector chosen in the first period resulted in considerable wealth transfer to subjects 14/1 and 14/3 at the expense of 14/2 in particular. However, subject 14/2 was receiving a positive net return from this allocation and his private incentive was to continue to post a contribution of 4 tokens since a lower contribution, given the contributions of the other subjects, would have resulted in the collective good not being provided.

Finally, as we noted above in Hypothesis 3, a subgame perfect Nash equilibrium is a sequence of the Nash equilibria of the single period game. We ran the session for several periods to permit the subjects to understand the members of their group. Yet, it is still necessary to check for end–period effects to be certain the single period prediction is met. Unfortunately, due to the multiplicity of the stage game equilibria the set of subgame perfect Nash equilibria is very large. The idea is that an outcome can be supported by "threats" of movements to an equilibrium in which the threatened player(s) are worse off than in the "desired" outcome.[23] All except the equilibrium in which the stage game equilibrium is played repeatedly may exhibit end game behavior. The lack of *explicit* end game behavior in the experiment (see Tables 1A, 1B and 2.11–2.21) lends tentative support to the view that the equilibrium the subjects are focusing on involves repeating a stage

[23] See Benoit and Krishna [1985] or Friedman [1986].

game equilibrium.

These conclusions must be quite tentative because of the possibility that what we have referred to as "learning" can be confounded with non-stationary subgame perfect equilibria. In other words, since we cannot guarantee that all believe they are playing a game of complete information, we cannot definitively separate the effects of "learning" from the non-endgame behavior arising from non-stationary subgame perfect Nash equilibrium.

5. Conclusion

We have reported on some experiments run using, as a basis, a game studied by Bagnoli and Lipman. Their analysis suggested that if people used strategies that constituted a proper equilibrium, then the equilibria of the game generated the efficient outcome. Our experiments clearly indicate that in the final 5 periods of the game, the participants always provided the public good (the efficient choice as we had chosen parameters that made the participants' valuations sum to more than the cost of the public good). Thus, it appears sensible to focus on the proper equilibria of the game under analysis.

Second, we have shown that this game is likely to eliminate virtually all of the free rider problems one normally fears may cause the private provision of a public good to be inefficient. Third, we have provided evidence concerning the effects of studying games of private provision of public goods that do not have the unsavory feature of a dominant strategy.

Our results clearly suggest that there are potential "natural" institutions which are capable of efficient private provision of public or collective goods. Indeed the use of a similar institution by the NDP (mentioned in the introduction) may be just such an example. Our experimental results are very strong. We have established a plausible naturally occurring environment wherein an equilibrium strategy for individual agents is to contribute positive amounts to the provision of a public good so as to produce the efficient decision. Our results indicate that voluntary, decentralized provision of such public goods can be theoretically and behaviorally predicted making it imperative that we once again attempt to determine whether public goods are provided efficiently. Further, if we were to determine that they were not, we would need to question why institutions had not arisen that would solve this difficulty.

Our results do indicate that skewed income or valuation distributions may make the attainment of an equilibrium more difficult. As the agents attempt to discover an equilibrium strategy they may sacrifice efficiency in that the good is not provided. Group 11 was successful in providing the good and in doing so efficiently in all but one of the final ten periods. By contrast, some of the other groups failed to have the good provided in many of the early periods. However. even these other groups approached the equilibrium fairly early in the session and were almost exactly on the equilibrium for the last five periods. Our results have provided some support for the Tiebout hypothesis although additional work on this subject is needed.

In the overwhelming majority of the cases the subjects entered contributions which were individually rational. "Overbidding" is not widespread. Any contribution which will have the good provided is rational thus we have no concept of "underbidding" as long as the good is provided. Subjects may engage in strategic contributing according to their estimates of the behavior of the others in their group.

The larger groups were demonstrably slower to learn the game as shown by their lower overall (all 14 periods) efficiency levels. However, even with ten persons these groups had settled to near the Pareto efficient equilibrium by the last five periods of the session.

Ultimately we intend to extend our experiments to cover the multiple streelight case (that is, to the question of how much of the public good is provided as well as whether any will be). Bagnoli and Lipman [1986] prove that the theorem holds for this case as well under more restrictive assumptions.

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APPENDIX

Experimental Instructions

This is an experiment in decision making. Several research organizations have provided funds for this research. The instructions are simple and, if you follow them carefully 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 each of five or ten persons. Each group will consist of the same five or ten persons for the duration of the session. The session itself will last for ten or fourteen periods. The number of periods will be announced prior to the start of the session. In each period you will be required to make a decision and your total income from the session will depend on these decisions.

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.

The actual number of persons in your group along with other information is reported on a set of information slips that have been provided to you. You have been given one slip for each period of the session.

At the beginning of each period you will receive an income in tokens. These tokens may be exchanged for money at a rate stated on your information slips. Also provided on these slips is the income of each of the other persons in your group. This is private information. That is, you are not to reveal it to anyone else in the room.

You will be asked to post a contribution in each period. You will have three minutes to enter your contribution. You may enter any contribution from zero up to the amount of your income for the period. Contributions in excess of your income will not be accepted. Enter your contribution on the slip of paper provided. You may contribute part tokens, eg. 4.5 tokens.

Once the contributions have been entered, the slips will be collected by the persons running the experiment. If the sum of the contributions of the persons in your group meets or exceeds the threshold level that is stated on your information slips you will each receive an additional income of tokens. The size of this addition for the group and for yourself is also stated on the information slips. Your total income for the period will be your initial income *plus* the additional tokens *minus* your contribution.

If the sum of the contributions is less than the threshold level the additional tokens will not be provided. In this event your contribution will be returned to you and your total income for the period will simply be your original income.

At the end of each period the persons running the experiment will inform you whether your group has obtained the additional tokens. The total contribution of your group but not the contributions of the individual members will be posted on the board.

A set of information slips has been prepared for you. You have one slip for each period. On each slip your ID number and the period appear in the upper right corner. As well the slip tells you your income for the current period, the incomes of the other members of the group, the number of persons in your group, and the share of the additional tokens which will go to each member of your group. Finally, the slip contains a blank where you are required to enter your contribution for the period. An example slip and session are reported below.

Example Information and Session

(a) Information Slip

Period # 1
ID # 29

Number of persons in your group is 5.

Threshold contribution of your group is 12.5 tokens.

If this contribution is met or exceeded the group will receive 25 additional tokens. Your share of the additional tokens is 5 tokens. All members of your group receive this share.

Your Income	4.00 tokens
Other persons' incomes	4.00 tokens
	4.00 tokens
	4.00 tokens
	9.00 tokens
Your contribution	________

That is, your income is 4.00 tokens for this period. Of the others in your market, three have an income of 4.00 and one an income of 9.00.

(b) Session: The required total contribution is 12.50 tokens. Say you contribute 2.00 tokens. Now, if the total is at least equal to 12.50 then you will receive 5.00 tokens plus your initial income of 4.00 tokens less your 2.00 token contribution. Your total income for the period is 7.00 tokens. This will be exchanged for money at the end of the session by the person running the experiment.

If the total contribution of your market is less than 12.50 tokens you will receive your initial income of 4.00 tokens for the period regardless of your own posted contribution. That is, the additional tokens will not be provided in this period and your posted contribution will be returned to you. This will be exchanged for money at the end of the session by the person running the experiment.

Are there any questions?

Information Slip

Period#____________

ID# ______

The Number of persons in your group is ____________

Threshold contribution of your group is ____________ tokens. If this contribution is met or exceeded the group will receive ____________ additional tokens. Your share of the additional tokens is ____________ tokens. All members of your group receive the same share.

Your Income ____________ tokens

Other persons' incomes

____________ ____________

____________ ____________

____________ ____________

____________ ____________

____

Your contribution ____________

Incomes and Valuations

Group 11		Group 12		Group 13	
Subject ID*	Income	Subject ID	Income	Subject ID	Income
11/1	11.0	12/1	16.0	13/1	16.0
11/2	11.0	12/2	16.0	13/2	14.0
11/3	11.0	12/3	8.0	13/3	11.0
11/4	11.0	12/4	8.0	13/4	7.0
11/5	11.0	12/5	7.0	13/5	7.0

*The ID numbers use the format: Group Number/ Subject Number
Each subject's valuation of the public good was 5 tokens.

Group 14		Group 15		Group 16	
Subject ID*	Income	Subject ID	Valuation	Subject ID	Valuation
14/1	12.0	15/1	10.0	16/1	10.0
14/2	12.0	15/2	10.0	16/2	8.0
14/3	12.0	15/3	2.0	16/3	5.0
14/4	12.0	15/4	2.0	16/4	1.0
14/5	7.0	15/5	1.0	16/5	1.0

*The ID numbers use the format: Group Number/ Subject Number
Group 14's valuation of the public good was 5 tokens each.
Each person in groups 15 and 16 had the same income, 11 tokens.

Group 17	
Subject ID	Valuation*
17/1	6.0
17/2	6.0
17/3	6.0
17/4	6.0
17/5	1.0

*Equal incomes, 11 tokens

Group 20		Group 21	
Subject ID	Income	Subject ID	Income
20/ 1	11.0	21/ 1	16.0
20/ 2	11.0	21/ 2	16.0
20/ 3	11.0	21/ 3	16.0
20/ 4	11.0	21/ 4	16.0
20/ 5	11.0	21/ 5	8.0
20/ 6	11.0	21/ 6	8.0
20/ 7	11.0	21/ 7	8.0
20/ 8	11.0	21/ 8	8.0
20/ 9	11.0	21/ 9	7.0
20/10	11.0	21/10	7.0
Each subject's valuation was 5 tokens.			

Table 1A					
Total Contributions by Group in Tokens					
Period	Group Number				
	11	12	13	14	15
1	20.0	10.5	15.0	12.5	17.0
2	14.5	13.0	11.0	12.5	15.2
3	12.0	12.5	14.5	12.5	11.5
4	13.0	12.0	13.5	12.5	10.0
5	12.5	12.5	11.0	12.5	13.5
6	12.0	10.0	12.5	12.5	12.8
7	12.5	13.0	12.5	12.5	12.8
8	12.5	12.5	12.0	12.5	12.5
9	12.5	13.0	12.5	12.5	12.5
10	12.5	12.3	12.5	12.5	12.5
11	12.5	13.0	12.5	12.5	12.7
12	12.5	12.0	12.5	12.5	12.5
13	12.5	12.5	12.5	12.5	12.5
14	12.5	13.0	12.5	12.5	12.5

Table 1B				
Total Contributions by Group in Tokens				
Period	Group Number			
	16	17	20	21
1	24.0	18.0	38.0	29.5
2	16.5	14.1	28.5	25.5
3	12.0	13.2	23.3	25.0
4	12.0	12.5	17.2	24.0
5	15.0	12.5	23.5	19.5
6	14.0	12.5	25.5	23.5
7	13.5	12.5	25.5	24.5
8	13.0	12.5	26.5	26.5
9	13.5	12.5	24.0	25.0
10	13.0	12.5	25.2	26.0
11	13.0	12.5	24.25	25.0
12	13.0	12.5	25.0	25.0
13	13.0	12.5	25.0	25.0
14	12.5	12.5	25.0	28.5

Table 2.11					
Group 11					
Period	1	2	3	4	5
1	3.5	4.5	3.5	5.5*	3.0
2	3.0	4.0	1.5	3.5	2.5
3	2.5	3.0	1.5	3.0	2.0
4	2.5	3.0	2.0	3.0	2.5
5	2.5	3.0	2.0	2.5	2.5
6	2.5	2.5	2.0	2.5	2.5
7	2.5	3.0	2.0	2.5	2.5
8	2.5	3.0	2.0	2.5	2.5
9	2.5	3.0	2.0	2.5	2.5
10	2.5	3.0	2.0	2.5	2.5
11	2.5	3.0	2.0	2.5	2.5
12	2.5	3.0	2.0	2.5	2.5
13	2.5	3.0	2.0	2.5	2.5
14	2.5	3.0	2.0	2.5	2.5

Table 2.12					
Group 12					
Period	1	2	3	4	5
1	3.0	3.0	2.5	2.0	0.0
2	4.0	3.0	2.5	2.5	1.0
3	3.5	3.0	2.5	2.5	1.0
4	3.5	2.5	2.5	2.5	1.0
5	3.5	3.0	2.5	2.5	1.0
6	3.5	3.0	2.5	0.0	1.0
7	4.0	3.0	2.5	2.5	1.0
8	3.5	3.0	2.5	2.5	1.0
9	4.0	3.0	2.5	2.5	1.0
10	3.5	2.8	2.5	2.5	1.0
11	4.0	3.0	2.5	2.5	1.0
12	3.0	3.0	2.5	2.5	1.0
13	3.5	3.0	2.5	2.5	1.0
14	4.0	3.0	2.5	2.5	1.0

Table 2.13					
Group 13					
Period	1	2	3	4	5
1	4.0	3.0	4.0	2.0	2.0
2	3.5	2.5	3.0	1.0	1.0
3	4.5	3.5	3.5	1.5	1.5
4	4.0	3.0	3.5	1.5	1.5
5	3.0	2.5	3.0	1.0	1.5
6	3.5	3.0	3.0	1.5	1.5
7	3.5	3.0	3.0	1.5	1.5
8	3.5	3.0	3.0	1.5	1.0
9	3.5	3.0	3.0	1.5	1.5
10	3.5	3.0	3.0	1.5	1.5
11	3.5	3.0	3.0	1.5	1.5
12	3.5	3.0	3.0	1.5	1.5
13	3.5	3.0	3.0	1.5	1.5
14	3.5	3.0	3.0	1.5	1.5

Table 2.14					
Group 14					
Period	1	2	3	4	5
1	2.5	4.0	2.5	3.0	0.5
2	2.5	4.0	2.5	3.0	0.5
3	2.5	4.0	2.5	3.0	0.5
4	2.5	4.0	2.5	3.0	0.5
5	2.5	4.0	2.5	3.0	0.5
6	2.5	4.0	2.5	3.0	0.5
7	2.5	4.0	2.5	3.0	0.5
8	2.5	4.0	2.5	3.0	0.5
9	2.5	4.0	2.5	3.0	0.5
10	2.5	4.0	2.5	3.0	0.5
11	2.5	4.0	2.5	3.0	0.5
12	2.5	4.0	2.5	3.0	0.5
13	2.5	4.0	2.5	3.0	0.5
14	2.5	4.0	2.5	3.0	0.5

Table 2.15					
Group 15					
Period	1	2	3	4	5
1	6.0	5.0	6.0*	0.0	0.0
2	6.0	4.2	5.0*	0.0	0.0
3	5.5	4.0	2.0	0.0	0.0
4	6.0	4.0	1.0	0.0	0.0
5	6.5	4.5	2.5*	0.0	0.0
6	6.3	4.5	2.0	0.0	0.0
7	6.3	4.5	2.0	0.0	0.0
8	6.0	4.5	2.0	0.0	0.0
9	6.0	4.5	2.0	0.0	0.0
10	6.0	4.5	2.0	0.0	0.0
11	6.0	4.5	2.0	0.0	0.0
12	6.0	4.5	2.0	0.2	0.0
13	6.0	4.5	2.0	0.0	0.0
14	6.0	4.5	2.0	0.0	0.0

Table 2.16					
Group 16					
Period	1	2	3	4	5
1	6.0	6.0	4.0	3.0*	5.0*
2	4.0	7.0	3.5	1.0	1.0
3	3.0	5.0	3.0	0.5	0.5
4	3.5	4.0	3.5	0.5	0.5
5	5.5	5.0	3.5	1.0	0.0
6	5.0	5.0	3.0	1.0	0.0
7	4.5	5.0	3.0	1.0	0.0
8	4.5	5.0	3.0	0.5	0.0
9	5.0	5.0	3.0	0.5	0.0
10	5.0	5.0	2.5	0.5	0.0
11	5.0	5.0	2.5	0.5	0.0
12	5.0	5.0	2.5	0.5	0.0
13	5.0	5.0	2.5	0.5	0.0
14	5.0	5.0	2.5	0.5	0.0

Table 2.17					
Group 17					
Period	1	2	3	4	5
1	4.0	5.5	2.5	3.5	2.5*
2	2.5	6.0	2.5	3.0	0.1
3	2.3	5.5	2.5	2.8	0.1
4	2.2	5.0	2.5	2.7	0.1
5	2.2	5.0	2.5	2.7	0.1
6	2.2	5.0	2.5	2.7	0.1
7	2.2	5.0	2.5	2.7	0.1
8	2.2	5.0	2.5	2.7	0.1
9	2.2	5.0	2.5	2.7	0.1
10	2.2	5.0	2.5	2.7	0.1
11	2.2	5.0	2.5	2.7	0.1
12	2.2	5.0	2.5	2.7	0.1
13	2.2	5.0	2.5	2.7	0.1
14	2.2	5.0	2.5	2.7	0.1

Table 2.20										
Group 20										
Period	1	2	3	4	5	6	7	8	9	10
1	2.0	8.0*	5.5*	3.0	3.0	2.5	4.0	2.5	2.5	5.0
2	1.0	8.0*	4.5	1.0	2.0	1.0	3.0	2.5	2.5	3.0
3	1.0	6.0*	3.0	0.0	2.0	2.0	2.8	2.5	1.0	3.0
4	1.0	2.5	0.7	0.0	2.0	2.5	3.0	2.5	1.0	3.0
5	2.0	2.5	0.0	2.0	3.0	2.5	3.0	2.5	2.0	4.0
6	2.5	2.5	1.0	1.5	3.5	3.0	3.0	2.5	2.0	4.0
7	2.5	2.5	1.0	2.5	3.0	2.5	3.0	2.5	2.0	4.0
8	2.5	2.5	2.0	2.5	3.0	2.5	3.0	2.5	2.0	4.0
9	2.5	2.5	1.5	2.0	3.0	2.5	2.5	2.5	2.0	3.0
10	2.5	2.5	1.7	2.5	3.5	2.5	2.5	2.5	2.0	3.0
11	2.5	2.5	2.0	2.25	2.5	2.5	2.5	2.5	2.0	3.0
12	2.5	2.5	2.0	2.5	2.5	3.0	2.5	2.5	2.0	3.0
13	2.5	2.5	2.0	2.5	2.5	3.0	2.5	2.5	2.0	3.0
14	2.5	2.5	2.0	2.5	2.5	3.0	2.5	2.5	2.0	3.0

Table 2.21										
Group 21										
Period	1	2	3	4	5	6	7	8	9	10
1	2.0	2.5	5.0	4.0	3.0	3.0	3.0	2.5	3.0	2.5
2	1.0	2.5	4.5	2.5	2.0	3.0	3.0	2.5	3.0	2.5
3	1.0	2.5	4.0	2.5	2.0	3.0	2.0	2.5	3.0	2.5
4	1.0	2.5	4.0	2.5	2.0	3.5	2.0	2.5	2.0	2.5
5	0.0	1.5	4.0	2.5	2.0	3.5	2.0	0.0	2.0	2.5
6	0.0	3.0	4.0	2.5	2.5	4.0	2.0	0.0	3.0	2.5
7	1.5	2.5	4.0	2.5	2.5	4.0	2.0	0.0	3.0	2.5
8	1.0	2.5	4.0	3.0	3.0	4.0	2.0	1.0	3.0	2.5
9	1.0	2.5	4.0	3.0	2.5	3.5	2.0	1.5	2.5	2.5
10	1.0	3.5	4.0	3.0	2.5	3.5	2.0	2.5	2.5	2.5
11	1.0	2.5	4.0	3.0	2.0	3.5	2.0	2.5	2.0	2.5
12	1.0	2.5	4.0	2.5	3.0	3.0	2.0	2.5	2.0	2.5
13	1.0	2.5	4.0	2.5	3.0	3.0	2.0	2.5	2.0	2.5
14	2.0	2.5	4.5	2.75	3.0	3.5	2.0	2.5	3.0	2.5

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