When Self-Interest is Self-Defeating: The Public Goods Experiment as a Teaching Tool

Robert G. Nelson and Richard O. Beil, Jr.*

Abstract

This simple classroom experiment demonstrates many of the behavioral phenomena associated with the voluntary provision of a public good. The mechanics of the game are explained in detail and complete instructions are provided, as well as suggestions for follow-up lectures. Influences such as anonymous voting, persuasion, returns to free-riding, and duration of association can be explored in connection with concepts of incentives, individual rationality and group welfare. A number of variations and extensions can be used to incorporate prisoners' dilemmas, incentive compatible mechanisms, negative externalities, and Coasian bargaining.

Key Words: teaching, experimental economics, public goods

When it comes to the free rider problem, the standard textbook exposition on voluntary financing of public goods can seem both paradoxical and pedantic. Consider one such exposition (representative of many) from Stiglitz's textbook *The Economics of the Public Sector*:

> "But since every individual believes that he would benefit from the services provided regardless of whether he contributed to the service, he has no incentive to pay for the services voluntarily. That is why individuals must be forced to support these goods through taxation." (p. 120)

Such statements are paradoxical because although individuals are supposed to have no incentive to contribute we do in fact observe many highly successful examples of voluntary contributions to public goods. Such statements are pedantic, or at least overly general, in that while taxation is usually the recommended solution, many organizations do not have such authority, and there are other mechanisms that can be used to elicit contributions without coercion.

In introducing the subject to students we may argue that universal free-riding can be predicted from our simple theory of self-interested, "rational" choice--a theory that served us well when we lectured on markets for excludable, private goods. But now we encounter a class of goods for which self-interest is both rational and self-defeating at the same time! From the perspective of the experimental economist or game theorist these issues are simply different facets of the principle that "institutions matter"--it is not so much a case of

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different goods, or market failure, or innate greed, as it is that the institution (or set of rules) that we typically use to represent the market for public goods tends to favor non-cooperation.

Still, simplistic and inaccurate representations abound. In their review of the instructional literature on free-riding, Asch and Gigliotti comment that the remarkably uniform treatment of free-riding in economics textbooks "misses the opportunity to show students how economic analysis may come to grips with a set of apparently inconvenient facts and with the not uncommon opinion that economists are ethical nihilists, if not worse." (p. 34) Indeed this not uncommon opinion has led to recurrent accusations that we indoctrinate our students to be selfish. These charges range from provocative titles like "Does Studying Economics Inhibit Cooperation?" and "Economists Free Ride, Does Anyone Else?" in professional journals (Frank et al.; Marwell and Ames) to recent disparaging remarks in the popular press such as "Economists are not merely dismal, it appears, but selfish and uncooperative, as well" (Anon., p. 71).

Rather than defend or perpetuate these stereotypes and prejudices, we can transform these incongruities into a "teachable moment" through a simple classroom experiment that is easy to conduct, fun to play, and rich in empirical content. Just as laboratory exercises are an integral part of the curricula of most scientific disciplines, agricultural economics can also benefit from the selective use of laboratory exercises in experimental economics. In this paper we describe in detail a prototypical one-class-period experiment and then discuss modifications and variations of the procedure suitable for an extended set of follow-up lectures on public goods.

Background and Rationale for the Instructor

The conditions of the classroom laboratory are not intended to mimic the real world. Quite the opposite, the laboratory environment is specially designed to give the experimenter control over as many variables as possible. In this experiment the instructor has control over several key factors that are now widely accepted to affect the extent of free-riding, but that are not articulated in the simple theory of rational choice. The public good is "pure" in that it is nonrival in consumption and nonexclusionary in its benefits. Moreover, every individual shares equally in the pecuniary benefits. The instructor is in the singular position of controlling each student's marginal valuation of the good, as well as the group optimum. The instructor can also vary the group size, period of association, incentive structure, and conditions of anonymity and communication.

This experiment illustrates a behavioral response (free-riding) that reduces the efficiency of an allocation mechanism (private funding of a public good) even though that mechanism has the potential to make all the participants better off and none worse off. It demonstrates a case where the "invisible hand" of rational, utility maximizing self-interest can fail to serve the interests of society. Furthermore, students often do not fully appreciate the difficulties in organizing for collective action. This classroom experiment is an entertaining way to reveal some of these complexities of human behavior.

The Mechanics of the Game

A significant advantage of this experiment is that it can be conducted in one class period and students will gain an immediate appreciation of the dynamics of collective action. However, the instructor may need additional time to record earnings and provide summary statistics.

It is important for students to understand the nature of the payoff table early if they are to make deliberate decisions rather than random choices, and this may take a few rounds of practice. However, assuming the instructions are clear, it should not be necessary to explain any theory to the students in order for them to start making choices in the game. Before conducting the experiment, we also try to avoid describing the funding objective with specific examples like lighthouses or national defense so as not to bias the marginal valuation (the instructions just call it a "Public Good").

To set up this experiment the instructor gives each student an endowment--$0.50 or its equivalent in bonus points--at the beginning of each round. Each student must then decide whether to give the endowment to fund a public good, or keep the endowment. They communicate this decision by

writing their name and their vote (to "give" or "keep") on a slip of paper and handing it to the instructor. The instructor counts the number of "give" slips and announces this number to the class. Students then look up their individual earnings for that round from the table in their instructions. In our example, if five people (or more) give, then everyone makes as much as (or more than) their original $0.50 endowment. The more people who give, the more everyone makes. But a Keeper always makes $0.50 more than a Giver.

In contrast to the stylized facts of rational choice, but just like the real world, the most frequently observed outcome of this experiment is that some proportion of the class gives in each round and another keeps. Complete cooperation is exceptional, but wholesale free-riding is extraordinary. As students anticipate the end of the experiment (which is usually the end of the class period) there are often dramatically fewer Givers and more Keepers. If allowed, some interesting attempts by spokespersons to stimulate cooperation may develop in intermediate rounds but, with no mechanism to monitor voting and penalize defectors, full cooperation tends to be short-lived.

Although "dollars and cents" are used in discussing the instructions and payoffs, bonus or participation points toward the course grade can also be used effectively to motivate students to play the game in earnest. For example, we might offer one point added to the midterm grade for every $10 earned in the experiment. Obviously, the results of public goods experiments are sensitive to the returns to free-riding. If there is no payoff to free-riding then we should expect to see higher levels of cooperation. This is an important real-world variable that may be discussed in a subsequent class concerning the conditions under which one would find cooperation more or less effective.

Table 1 in the Instructions for the Student (Appendix) would need to be extended for classes larger than 25, but the general rule is simple: multiply the number of "gives" by a constant to get the "gives" payoff (we used a constant of 0.10 in the table); add the endowment to this to get the "keeps" payoff. Small classes (n<5) would need a payoff table where n givers would earn at least as much as their endowment. Very large classes could be divided into teams. This introduces the element of group dynamics in decision-making, an element not found in the classical model of individual choice, but one that corresponds to many real-world institutions.

As demonstrated in the "Sample Results" section, the instructor may allow talking among class members as an effort to persuade more members to be Givers, but anonymity in actual voting should be preserved. Since many people perceive the experiment as dealing with sensitive moral issues such as fairness, cooperation, fidelity and solidarity, we strive to keep the balloting process confidential. The results of these experiments are quite sensitive to whether participants feel that strict anonymity can and will be maintained. In the terminology of game theory, the potential for "monitoring" is a significant variable in determining the extent of free-riding.

In many economics experiments talking among subjects is prohibited in order to inhibit strategic signalling and collusion. Relaxation of this convention is relatively harmless in this experiment and may be used to illustrate the role of "social entrepreneurs" (McCaleb and Wagner) in devising tactics to facilitate cooperation. The instructor may wish to discourage talking in early rounds and then allow it in later rounds. The number of Givers usually increases with appeals from self-appointed advocates of cooperation whose exhortations can be quite engaging. Such rules of communication are yet another variable in determining the effectiveness of cooperative action.

A sustained high level of contributions to the public good is unlikely when using the payoff table provided here. This is predictable mainly because of the substantial returns to free-riding that are built into the table. Another destabilizing element is introduced when students know the game is going to end with the class period; they tend to display more self-interest in later rounds.

Sample Results

Figure 1 shows the results of an experiment in a class of 16 students. The experiment was conducted before the topics of public goods and free-riding were introduced in lecture. The session occupied an entire 50-minute class period. Talking was not allowed in the first four rounds, but by the

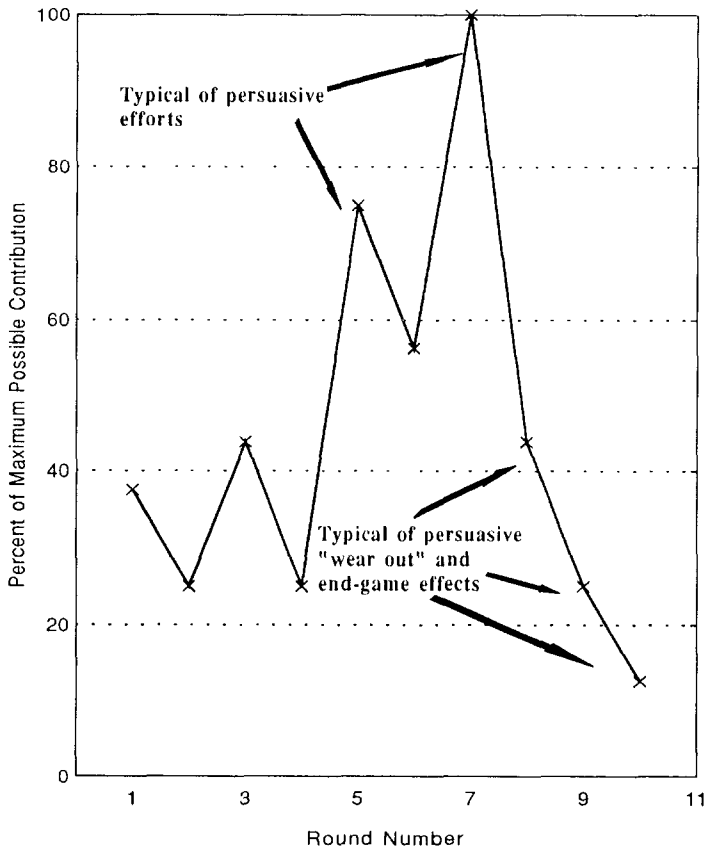
Table 1. Payoff Table for the Public Goods Game

If this many people choose "give"	You will get this much for choosing:	
	"give"	"keep"
0	0.00	0.50
1	0.10	0.60
2	0.20	0.70
3	0.30	0.80
4	0.40	0.90
5	0.50	1.00
6	0.60	1.10
7	0.70	1.20
8	0.80	1.30
9	0.90	1.40
10	1.00	1.50
11	1.10	1.60
12	1.20	1.70
13	1.30	1.80
14	1.40	1.90
15	1.50	2.00
16	1.60	2.10
17	1.70	2.20
18	1.80	2.30
19	1.90	2.40
20	2.00	2.50
21	2.10	2.60
22	2.20	2.70
23	2.30	2.80
24	2.40	2.90
25	2.50	3.00

fourth round some students were exhibiting considerable frustration at not being able to communicate with other students (presumably to explain the payoff table and bring attention to the benefits of cooperation). At this point the instructor offered to relax the rules and allow the students to talk things over. The next round showed a substantial increase in contributions, but this eroded in Round 6. The students conversed again and in Round 7 they achieved 100 percent of the maximum contribution rate. By this time the end of the class period was imminent and further attempts to sustain the coalition were progressively less successful until the last round was announced and the game ended with only two Givers. About one "dollar" per person per round was earned on the average over the ten rounds, at a dollar-to-bonus point conversion rate of 10:1.

A small fraction of students were free-riders in every round (except the seventh). A few consistently contributed throughout the experiment. Most alternated between "giving" and "keeping." Ironically, a sentiment commonly expressed by this group was "I tried to be cooperative but found it didn't pay because others were too greedy!"

Figure 1. Contributions to the Public Good, by Round; 16 Players



Debriefing: What the Experiment Demonstrates

After several rounds of play, students have accumulated tangible experience in the dynamics of free-riding behavior. The economic principles underlying this phenomenon can be the topic of subsequent lectures. Our exposition is something like the following.

Free-riding can lead to a condition that is sometimes described as "market failure" whereby the private market fails to efficiently supply a good or service for which there is ample, though perhaps latent, demand. Because free-riders do not reveal their true demand for public goods, it is often argued that public financing is the only way to provide such goods, with the allocation mechanisms of choice being majority rule and fixed tax shares. Nevertheless, in the real world we often see examples of private financing by voluntary contributions that result in the provision of public goods such as college athletics programs, churches, art exhibits, and public broadcasting. An important distinction is that in the real world we do not know each person's marginal valuation of the public good. In the case where some people perceive their marginal benefit to be less than the marginal cost imposed, public financing by taxation results in the antithesis of free-riding, a phenomenon wryly described by Gordon Tullock as "coerced carrying" (McCaleb and Wagner).

A real-world agricultural example relates to generic advertising of a commodity like beef, butter, or broccoli. By definition, any increase in the demand for a generic product benefits all producers of that product. The benefits of advertising cannot be captured privately the way they can if the product has a private label, brand, or trademark. Thus, generic advertising is often funded by a "check-off" program that automatically charges producers some percentage of their input costs or sales revenues. Some of these programs have a refund provision whereby a producer can ask that the amount charged under the check-off be refunded

in full or in part. Producers that exercise this refund provision could be characterized as free-riders.

Students often suggest that free-riding could be eliminated if everyone were required to contribute to the Public Good. In fact, most generic promotion programs have responded to perceived free-riding in this very way, terminating their refund provisions when refund levels reached disturbing proportions. For the Honey Board this occurred when refunds reached 13 percent; for the National Potato Promotion Board, 18 percent; for the Cotton Board, 35 percent; and for the National Egg Board, 45 percent (Forker and Ward pp. 92 and 108). However, not all organizations are vested with the authority to tax and, for those that are, coerced carrying can be an unwelcome consequence.

Students also complain that their main frustration with the game is that they are not allowed to know how other students had voted. Members of international cartels like OPEC voice a similar complaint when they cannot effectively monitor cartel members' actions and penalize them for departures from the monopoly price. Indeed, the economics of public goods is similar in many ways to that of oligopolies.

A homework question on "What do you think were important factors determining contributions in each round?" can generate some penetrating insight and novel extensions. For example, one student commented that the experiment was "like a prediction game" in that his decisions were based on anticipations of how many others would give--a fair description of the process of rational expectations formation. Another student remarked that persuasive efforts were like advertising, and we noted that they do display some of the same "wearing out" effects in subsequent periods. Responses to the question "What improvements can you suggest to increase voluntary contributions?" produced such refinements as "ask for a show of hands of *intentions* to give before each round" and "put the givers' slips into a lottery pool, draw names at random, and give a bonus to the winners."

While we have used the Public Goods game primarily in lower-division undergraduate classes in marketing and microeconomics (with both majors and non-majors) it can be adapted to intermediate, advanced and graduate classes. Such extended expositions could use game theory to formalize the notion of free-riding as a Nash equilibrium that is Pareto-dominated by the nonequilibrium outcome (full contributions). Students could be challenged to design an allocation mechanism that is non-dictatorial, Pareto-optimal, and strategy-proof (Ledyard). Majority rule satisfies these conditions, but only if there are no more than two possible allocations. For three or more allocations an impossibility theorem has established the nonexistence of such an optimal mechanism (Satterthwaite). Although no dominant alternative institution has been developed, numerous rules for making committee decisions have evolved, and some unconventional mechanisms have been proposed such as the Wicksell-Lindahl tax scheme, Thompson's D-Process, and the Groves-Ledyard mechanism (Feldman).

Variations and Extensions of the Game

The research literature of experimental economics contains many extensions and elaborations on the theme of public goods provision. Most of these investigations are beyond the scope of the basic principles under discussion here, or are oriented toward research rather than teaching applications. However, there are several variations that may prove instructive in the undergraduate or graduate classroom setting.

Random Endpoint

One simple variation is to make the duration of the game more uncertain. The propensity for cooperation to deteriorate is not as predictable if players do not know when the game will end, especially if it is perceived to continue well beyond one class period in the future. A game with a random endpoint can be used to examine this effect on the sustainability of cooperation. The random endpoint can be determined by rolling a pair of dice or picking a card from a shuffled deck. When a certain number or card appears, the game ends. Although not common in real-world applications, endpoint anticipation has been noted as an important treatment variable influencing the

degree of cooperative action in research experiments; the "one-shot" game is an extreme case (Andreoni).

Variable Contributions

Another institutional modification allows the student to make variable contributions to the public good instead of the all-or-nothing choice described above. While this variation is more representative of real-world situations, it reduces the number of rounds that can be played in a class period because instead of just *counting* "gives" the instructor now has to *sum* the different contributions on all the slips of paper before the value of the public good can be announced. Typically the instructor adds some percentage to the sum of the contributions to determine the value of the public good.

This variation has been adapted for classroom use by Brock for repeated play among teams of students, and by Sulock for a one-shot game where students contribute their own money. Brock suggests a homework exercise to derive the market demand curve for the public good by vertically summing the willingness to pay of the individual teams.

Prisoner's Dilemma

Brock also describes a game-theoretic interpretation of the public goods game that is constructed as a Prisoner's Dilemma. Since our version uses all-or-nothing contributions it fits this interpretation better than the variable contributions version. For a game with 20 players, the Prisoner's Dilemma payoff matrix that corresponds to table 1 is shown in figure 2. The larger type indicates "your payoff," while the smaller type indicates "every other player's payoff" assuming they all do the same thing.

The game-theoretic exposition is particularly well-suited to illustrate why free-riding is a Nash equilibrium even though full cooperation is Pareto-dominant.

Provision Points

Isaac, Schmidtz, and Walker describe a modification in which contributions to the public good can be increased substantially. In this design the public good is provided only if total contributions reach some pre-specified threshold called a "provision point"; otherwise contributions are returned under a money-back guarantee. In the all-or-nothing case, the provision point can be constructed to render a Nash equilibrium where full contribution now Pareto-dominates the free-rider equilibrium. Again using an example with 20 players and table 1, the payoff matrix corresponding to a full-contribution provision point of 20 with a money-back guarantee is shown in figure 3.

Any provision point less than the full contributions case illustrated in figure 3 leads to a different set of incentives to free-ride. For example, with 20 players and a provision point of 19, figure 4 shows that "keeping" is the best strategy (if everyone else can be counted on to "give").

Figure 5 illustrates the results from a class of 44 students where the first six rounds followed the rules described above for the prototype game and the last six rounds used various provision points with the money-back guarantee. The provision points used in this game were suggested by class members. Round 7 had a provision point set at 30 and met this condition with 35 givers. Rounds 8, 9, and 10 fell short of their provision points and the refund option was exercised: round 8 required 35 givers but got only 28; round 9 required 35 givers but got only 25; round 10 required 43 givers but got only 41. Rounds 11 and 12 attained their provision points, which were both set at full contributions (44). Students apparently came to realize that any provision point less than full contributions faces the same free-rider problems as the basic game.

Bagnoli and McKee relate several instances where the provision point mechanism was used to obtain voluntary contributions to fund a public good. In 1979 a successful effort was made to hire a lobbyist to represent faculty welfare before the Oregon state legislature. All faculty in the state were asked to contribute to the lobbyist's annual salary, with the proviso that contributions would be returned if the funding objective ($30,000) was not

Figure 2. Payoff Matrix for 20 Players--Basic Game

		ALL OTHERS: give	ALL OTHERS: keep
YOU	give	2.00 / 2.00	0.10 / 0.60
YOU	keep	2.40 / 1.90	0.50 / 0.50

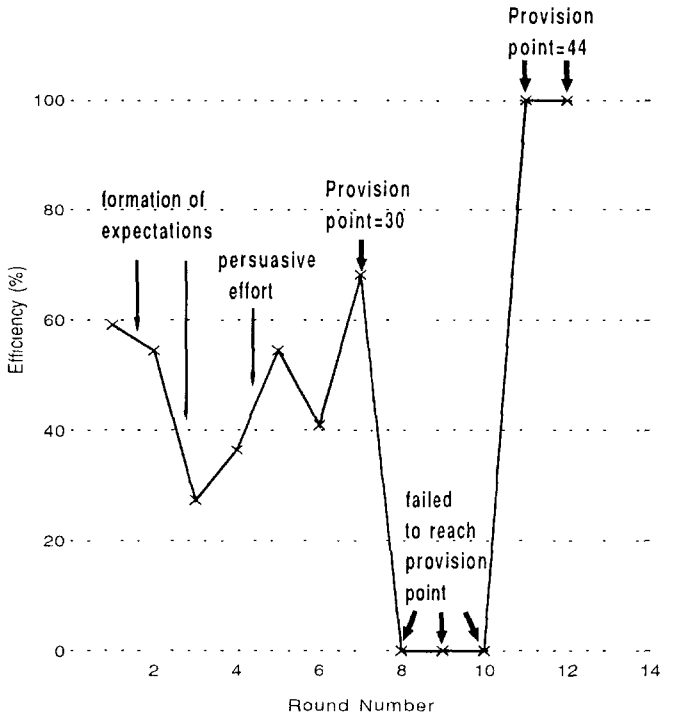
Figure 3. Payoff Matrix for 20 Players--Provision Point (=20) with Money-Back Guarantee

		ALL OTHERS: give	ALL OTHERS: keep
YOU	give	2.00 / 2.00	0.50 / 0.50
YOU	keep	0.50 / 0.50	0.50 / 0.50

Figure 4. Payoff Matrix for 20 Players--Provision Point (=19) with Money-Back Guarantee

		ALL OTHERS: give	ALL OTHERS: keep
YOU	give	2.00 / 2.00	0.50 / 0.50
YOU	keep	2.40 / 1.90	0.50 / 0.50

Figure 5. Basic Game (Rounds 1-6) Compared to Provision Point Game (Rounds 7-12); 44 Players



reached by a given date. The New Democratic Party in Manitoba, Canada used the approach on two occasions to secure additional contributions from larger donors, achieving their targets of $200,000 and $250,000 in 1980 and 1985 respectively (Bagnoli and McKee, p. 351). Applying the provision point mechanism to generic advertising of agricultural commodities could mitigate the negative effects of coerced carrying and reduce dependence on dictatorial processes such as those endorsed by Forker and Ward: "The free-rider issue will always exist in some form, but the negative effects can be mitigated through nonrefundable mandatory assessments on all of the volume going into the market area in which the demand-expansion program is to be conducted." (p. 258)

Negative Externalities

In addition to these variations on the voluntary contributions game there are several parallels and extensions that may find a place in the classroom exposition. So far the experiments described have focused on free-riding as a consequence of the non-exclusionary property in public goods. The non-rival property implicit in these games has generated only positive externalities. But when anyone can use the good and it can be depleted, as with an open-access resource like public grazing land, negative externalities can lead to the "tragedy of the commons".

Walker, Gardner, and Ostrom investigated these effects with experiments using a "common-pool-resource mechanism". Subjects could invest their token endowment in either of two markets. One market offered a modest but constant return. The other market appeared to offer a higher return except that as more people invested in it the return steadily decreased. Resource overuse caused rents in the second market to accrue at levels averaging only 5.7 percent of the optimum, a level of rent dissipation even lower than predicted by standard models of noncooperative behavior.

Market failure problems arising from negative externalities can sometimes be resolved if property rights are assigned and side payments are

allowed. Leuthold has adapted a Coasian bargaining experiment for the classroom. Students are paired and one is chosen as the "controller" who determines the number of units to be produced (say, units of water pollution abatement). The second player earns progressively higher returns for more units (because cleaner water is more valuable to him), while the controller earns progressively less (because he has to pay for cleaning the water). The payoff table is constructed so that both will benefit if the controller produces some units in exchange for part of the second player's earnings. The two players bargain over the number of units to be produced and the amount of the side payment. Leuthold reported that students bargained to the optimal number of units an average of 83 percent of the time.

Conclusions

Experiments are not just for researchers anymore. They can be an effective tool in teaching agricultural economics and are especially well-suited to involving students in the process of discovery. Moreover, student evaluations of the game consistently range from favorable to enthusiastic.

The attractive features of the prototype experiment described here are that it is easy to set up and quick to execute, and it demonstrates economic behavior in a novel way not duplicated by the classroom lecture or textbook reading. It provides students with an empirical foundation--a touchstone--that they can use to understand and appreciate more elaborate concepts of cooperative institutions, resource economics and public finance.

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Appendix

Instructions for the Student

This is an experiment in the private funding of a Public Good. Individual contributions from the members of a group are used to fund a good or service that will benefit all the members collectively, regardless of who contributed and who did not.

The experiment will last for several rounds. At the beginning of each round you will each be given a sum of money as an allowance. You can keep this allowance, or you can contribute it toward the Public Good. To indicate what you wish to do with your allowance, write your name on a slip of paper and then write either "**give**" if you wish to give your allowance toward the purchase of the Public Good, or write "**keep**" if you wish to keep your allowance for yourself. Fold the paper in half (so that no one else can see what you wrote), and send the paper up to the front of the room. When everyone's slip of paper has been collected, the instructor will count the slips of paper that say "**give**" on them and announce that number. Using the attached table (table 1) you can then figure out how much money you made in that round. Keep a running total of your earnings to hand in at the end of the experiment.

Take some time now to study the attached table. There are three columns on the table. The first column shows all the possible numbers of people in the class who could choose to "**give**" in a particular round. The middle column shows how much money each class member would receive depending on how many "**gives**" were counted. For example, if 15 people wrote "**give**" on their slip of paper then each one of these people would receive $1.50 (reading across the table from row 15). All the other people in the class (i.e. those who wrote "**keep**" on their slip of paper) would receive that amount *plus* the amount of their allowance (since they chose to keep this). This amount is shown in the third column. Notice that any value in the third column is always larger than its corresponding value in the second column by $0.50, the value of the allowance in each round. The key feature of this table is that *the more people that "**give**" the more everyone makes, but those who "**keep**" always make $0.50 more than those who "**give**".*

After the experiment ends, hand in your record of total earnings to the instructor.