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The assurance problem in a laboratory market*

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1. Introduction

In the most general terms, a public good exhibits the characteristic of non-excludability; its benefits are available both to those who help to provide it and those who do not. Two other important features of the public goods provision problem are (i) the mechanism or institution for providing the good and (ii) the incentive structure for potential providers. Among the most familiar institutions is the voluntary contributions mechanism (VCM) combined with an incentive structure such that, for a single period, low levels of contribution are a dominant strategy equilibrium, while some higher level of provision is Pareto-superior. There has been a considerable amount of experimental research on such an environment (see Isaac and Walker, 1987a, for a survey). The existence of such a dominant strategy equilibrium, however, is not the only potential source of problems for the VCM. In particular, under alternative environments a potential provider can have an incentive to contribute if, and only if, he or she has a credible guarantee that others will also contribute. Absent such a guarantee, the provider may withhold. An environment exhibiting these incentives but without such a guarantee is sometimes said to exhibit the *assurance* problem (see Schmidtz, 1987).

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In this paper, we examine prospects for the voluntary provision of public goods in the face of the assurance problem. We proceed by the modifying the economic environment of Isaac, Walker and Thomas (1984) so that the return to the public good has a discontinuity known as a "provision point." Specifically, in the new environment if contributions do not meet a specified level, the provision point, the return from the contributions is zero. At or above this critical level, the returns become positive. In the provision point environment, noncontribution is no longer a dominant strategy. On the contrary, the environment yields multiple Nash equilibria, some of which can be Pareto ranked.

The remainder of this paper is organized as follows: Section 2 reviews the public goods environment, and presents the experimental design for 18 initial experiments and offers some theoretical conjectures. The experiments discussed here are called the Design I experiments. Section 3 reports the data from the 18 Design I experiments. Section 4 discusses extensions into a different economic environment. We will refer to the set of 18 experiments presented in Section 4 as the Design II experiments. Section 5 offers some concluding comments.

2. Environment, design, and hypotheses: Design I

2.1. *Experimental setting*

We will report here a total of 18 new experiments. Also reported for purposes of comparison are data from seven experiments (using identical parameters but with no provision point) from Isaac and Walker (1988b). All experiments used subjects drawn from a population of University of Arizona undergraduate students. The subjects were currently enrolled in lower-level economics courses. Subjects were volunteers who had received a brief explanation of what is meant to be in an economics experiment. Emphasis was placed on the fact that no special background in economics was required. All subjects were experienced. That is, all subjects had previously participated in a previous VCM experiment, although with *different* parameters. Specifically, all experiments reported here have 4 participants while the "trainers" all had at least eight. No four-person group was drawn intact from a previous experiment. Further, "trainer" experiments did not include a provision point (i.e. payoffs were continuous in contributions). See Isaac, Walker and Thomas (1984) for a discussion of the role of "experience" in similar public goods experiments.

The experiments were conducted using the PLATO computer system. This system allows for minimal experimenter-subject interaction and insures that all subjects see identical instructions for a given experimental design. The use of the computer also facilitates the accounting process that occurs in each decision period and minimizes the subject's transactions costs in making decisions and recalling information from previous decisions.

2.2. *The voluntary contributions decision mechanism*

At the beginning of each experimental session participants were told that they would be participating in an economic market in which they would make investment decisions. It was explained to the paticipants that the computer system was used only to present the instructions and to act as the means for transacting their decisions. It was emphasized to individuals that their own decisions were "private information" appearing only on their screen and were not to be discussed with others.

The programmed instructions described to the participants the following decision problem: given a specific endowment of tokens (resources) each person would face a private decision of investing (allocating) those resources between an individual exchange (a private good) and a group exchange (a public good). The individual exchange was described as providing the investor with a $0.01 return for each token invested. This was true across all experiments. The group exchange was explained as an investment that yielded a specific return to the individual as well as the same return to all other investors. Thus, the payoff an individual received from the group exchange was explained as depending upon the total number of tokens invested in the group exchange by all participants. The payoff from the group exchange was given to each participant in the form of a table which presented the return to the individual for different levels of total tokens invested, from zero tokens up to the total number of tokens in the group. This table could be recalled during decisionmaking later in the experiment.

The information position of each participant can be described as follows. First, each participant knew his own total endownment of tokens as well as the total number of tokens in the group (248 total tokens in all the experiments reported here). Second, participants knew the size of the group and that each participant's return from the group exchange was identical. Third, each participant knew that there would be 10 decision trials, and that his token endowment would be the same for each trial. Finally, it was emphasized that each trial was binding and that the participant's total monetary return equalled the sum of the profits for each of the individual periods. At the end of each decision trial, each participant received a message stating his or her return for the just-completed individual and group exchanges, as well as the total number of tokens invested by the group in the group exchange. Before making a decision for any trial, a participant could recall this information for any previous period.[1]

The decision process itself operates as follows: In each period, the experimenters endow each of four participants with 62 tokens. Each participant then chooses an allocation of his tokens between the individual exchange and the group exchange for the immediate period. Let m_i represent individual i's contribution of tokens to the group exchange in a given period. The group exchange is the public good in the sense that each individual received a payment of:

$$\left[\frac{1}{4}\right] \cdot G\,(m_i + \sum_{j \neq i} m_j) \text{ cents}$$

where G (·) is an appropriately specified function and $\sum_{j \neq i} m_j$ is the sum of contributions from individuals other than i. In previous experiments, G (·) took the form of 1.2 times the total number of tokens invested. In such an environment, each individual's single-period dominant strategy is to contribute nothing, while total returns to the group were maximized at $m_i = 62$ for each person. In the experiments reported here, the G (·) function took the following form:

$$\begin{array}{ll} 1.2\,(\sum_i m_i) & \text{for } \sum_i m_i \geq m^+ \\ 0 & \text{for } \sum m_i < m^+ \end{array}$$

The critical point m^+ is called the provision point of the experiment.

2.3. A note on some prior results

A complete survey of all of the previous experimental work on VCM is not possible here. However, it will be useful to review briefly some important results from some of the experiments which have used what can be called a "free-riding" environment. We use this term to mean experiments for which a single decision trial, looked at in isolation, has a unique complete information equilibrium prediction of public goods provision levels below the social optimum. It is the elimination of the unique sub-optimal equilibrium which is the key distinction of the experimental design reported here.

The existing experimental literature overwhelmingly supports the conjecture that the VCM operating in a free-riding environment will elicit substantially suboptimal provision of the public good. However, the data are not uniformly consistent with the equilibrium predictions. This does *not* mean that the research always supports an "intermediate" conjecture that contributions will be significantly greater than the equilibrium predictions although less than the optimal levels. Marwell and Ames (1979) did find such an intermediate pattern in "one-shot" experiments. Isaac, McCue and Plott (1985), Kim and Walker (1984), Isaac, Walker and Thomas (1984) and Andreoni (1986) have all replicated, under a wide variety of conditions, contributions which begin at intermediate levels but then decay in multiple trials. This decay is sometimes, but not always, to levels of contributions so low as to provide essentially complete support for "strong" versions of the free-rider hypothesis.

Isaac, Walker and Thomas (1984) and Isaac and Walker (1988) have demonstrated that, even within the category of dominant strategy environments, replicable design features such as subject experience with the process and the marginal returns from the group good can influence the level of contributions and the pattern of the decay. Specifically, the results from these two papers show that groups with a low marginal per capita return (MPCR) from the group good were much more likely to decay close to "free riding" levels than were groups with higher MPCRs, even when the dominant strategy equilibrium predictions were identical. The MPCR was shown to be intimately related to some concepts of group size properties of public goods provision. Goetze and Galderisi (1988) have conducted similar experiments which separate in a 2 × 2 design high and low marginal benefits to others from high and low marginal benefits to oneself.

In summary, the results to date from VCM experiments in a free-riding environment consistently support the conjecture that suboptimal provision of public goods will obtain. In many cases, contributions are also higher than is predicted by the complete information equilibrium. However, there are replicable features of the environment which are likely, in repeated decisions, to produce a decay in contributions very close to the free-riding outcomes. This discussion is intended to form an informal backdrop as, in the research reported in this paper, we eliminate the single-period dominant strategy (free riding) property of the previous research using this basic design. In later sections of this paper, some of the data from prior experiments is reported as a formal benchmark for the current results.

2.4. Design, parameters and hypotheses

A total of 18 experiments were conducted using three different provision points: 248, 216, and 108 tokens (100, 87, and 44 percent of total tokens, respectively). These three levels of provision point have distinct incentive characteristics which will be discussed in more detail below. Six experiments were conducted in each condition, which we refer to as the high, medium, and low provision point conditions. Table 1 presents a summary of the experimental parameters.

Table 1. Experimental parameters

Common across all experiments

No. of persons in each group: 4

Per-capita return from the group exchange:

$$\begin{cases} \left[\left(\frac{1}{4}\right) \times 1.2 \times \sum_i m_i \right] \text{ cents} & \text{for } \sum_i m_i \geq m^+ \\ 0 \text{ cents} & \text{otherwise} \end{cases}$$

Total number of tokens in group: 248

Distribution of tokens: (62, 62, 62, 62)

Provision points

Low Provision Point (LPP): 108 tokens

Medium Provision Point (MPP): 216 tokens

High Provision Point (HPP): 248 tokens

Six experiments reported in Isaac and Walker (1988b) had no provision point

Notice that the group optimum remains for all tokens to be contributed to the public good. However, zero contribution is no longer a dominant strategy in any of the three cases. Instead, the provision point creates multiple Nash equilibria.[2]

For the high provision point (m^+ equal to 248 tokens), there are two Nash equilibria. One is a strong equilibrium at the group optimum (62, 62, 62, 62); the other is at zero contribution (0, 0, 0, 0). The former is Pareto superior to the latter. However, the efficient equilibrium is unstable in the following sense. If (62, 62, 62, 62) is a potential outcome, let any one participant deviate by a single token. Then, the best response for the other participants jumps to zero contribution. On the other hand, if any one participant adds a token to the inefficient equilibrium (0, 0, 0, 0), the best response for the other is to remain at zero contribution. This is the strategic essence of the assurance problem.

The complete Pareto ranking of equilibria disappears with m^+ equal to 216 tokens. In this case, any vector of contributions totalling 216 is a Nash equilibrium. Furthermore, each such vector Pareto-dominates the inefficient equilibrium, but collectively they form a set which cannot be Pareto ranked.[3] The situation is even more complicated with m^+ equal to 108 tokens. Some, but not all, vectors of contributions totalling 108 tokens are equilibria. For example, the vector (27, 27, 27, 27) is a Nash equilibrium, as is the vector (28, 26, 27, 27). However, the vector (62, 46, 0, 0) is not because person 1 can unilaterally increase his own profits by moving all 62 of his tokens to the individual exchange. Thus, the low and medium provision point conditions exhibit not only the assurance problem but also the conflict involved in choosing one of several positive-contribution equilibria. We will call this the "cheap riding" problem because it provides individual incentives to attempt to obtain an equilibrium outcome with unequal distribution of contributions.

With a multiplicity of equilibria, simply confining our consideration to a hypothesis which predicts a Nash equilibrium outcome is not very useful. What is needed are hypotheses as to which equilibria will occur. There are at least two conjectures which are relevant to the environment investigated here. We will refer to these as the "Focal-Point" hypothesis (in the sense of Schelling, 1960) and the "Assurance Problem" hypothesis. Under the focal point hypothesis, the change to the provision point environment should improve the efficacy of the voluntary contributions mechanism. Zero contribution is no longer a dominant strategy and is, in fact, Pareto dominated by a positive-contribution equilibrium. Furthermore, that equilibrium does not involve some abstract break-point unknown to the participants. The provision point is common knowledge and should serve as a focal point for individual decisions. With an emphasis on the drawing power of the Pareto-superior equilibria, the focal-point approach would suggest that the high provision point would be the most successful because (a) the "cheap rider" problem does not exist, and (b) the gains from moving away from zero contribution to the equilibrium are the greatest.

Under the "assurance problem" conjecture, however, virtually the opposite results would be expected. Unlike the continuous payoff function of previous research, small departures from equilibrium contributions by other participants can impose large penalties upon those attempting to contribute enough to obtain high provision equilibria. Thus, the provision point environment might bring forth less contribution. Further, it is in the high provision point situation that the monetary risk from the assurance problem is the greatest.

There exists some evidence from other experiments. Marwell and Ames (1980) report that removing a partial provision point caused no difference in their results. However, their experiments are "one shot" and cannot capture the well-documented decay phenomenon of iterated decisions (see Kim and Walker, 1984; Isaac, Walker and Thomas, 1984; Isaac, McCue and Plott, 1985; and Andreoni, 1986). Two recent papers (van de Kragt et al., 1986; and Dawes et al., 1986) have examined provision points in an environment in which subjects had a binary choice space: contribute \$5.00 or contribute nothing to a group good. The results from the latter paper are illustrative of both. The environment contained a provision point in the sense that all participants obtained exactly \$10.00 from the group good if the number of contributors was

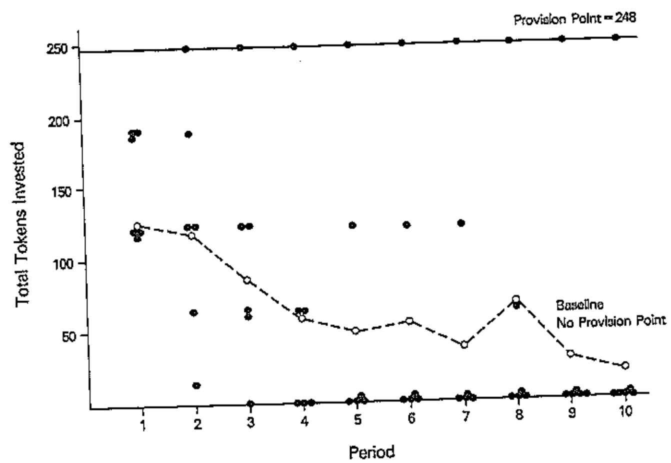

Figure 1a. Contributions per period – "high" provision point: six experiments

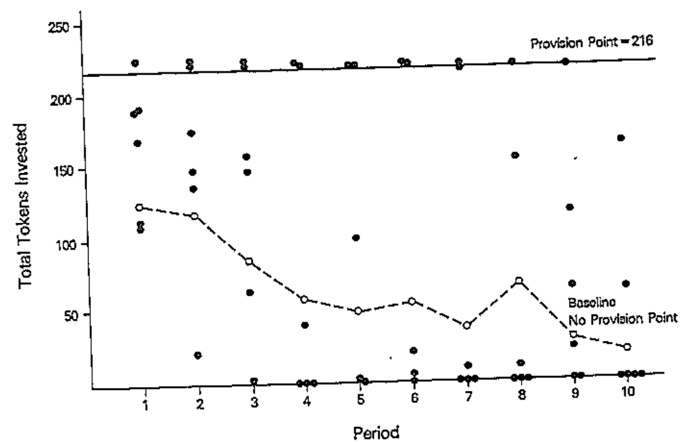

Figure 1b. Contributions per period – "medium" provision point: six experiments

greater than some critical number (3 or 5 out of seven participants). Pooled across all experiments, they found that 81 of 140 subjects contributed, and that the likelihood of a person being a contributor was negatively correlated with the person's expectation of sustaining a loss from contributing. They report a comparison of different contribution mechanisms, each with a provision point based upon number of contributors. We will discuss the implications of their results for alternative institutions in Section 4.

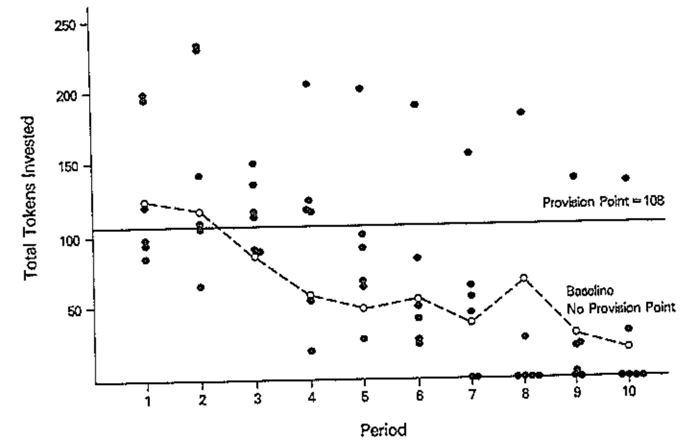

Figure 1c. Contributions per period – "low" provision point: six experiments

3. Experimental results: Design I

Figures 1a, 1b and 1c present the data from all 18 Design I experiments, for all ten periods. The vertical axis represents total group contribution to the group exchange measured in absolute token amounts (248 tokens equals 100 per cent optimum). The dotted line repeated in each figure is the mean across the six no-provision point experiments from Isaac and Walker (1986b). In addition, Table 2 lists the period-by-period total contributions to the public good for all 18 experiments.

The conclusions are organized along a series of observations. We begin with three observations regarding behavior in the early periods of the experiment.

Observation 1: In early periods, the "assurance problem" hypothesis is not supported by data on aggregate contributions.

Total contributions are substantial in early periods, and do not appear to be suffering when compared to the baseline of the prior no-provision point experiments. In fact, the mean of total contributions exceeds the baseline in all three conditions (see Table 3). Furthermore, mean total contributions are higher with HPP than with LPP, even though the assurance problem is worse because there is a greater loss from non-attainment in HPP for those who contribute a focal point amount. In period 1, 4 of the 18 groups reach their provision point. In period 2, this increases to 7 of 18.

Table 2. Total investment in group exchange. 18 Design I experiments

Experiment	Period 1	2	3	4	5	6	7	8	9	10
HPP1	186	124	0	0	0	0	0	0	0	0
HPP2	124	124	63	62	0	0	0	0	0	0
HPP3	189	248*	248*	248*	248*	248*	248*	248*	248*	248*
HPP4	117	12	60	0	2	2	1	1	1	1
HPP5	124	62	124	62	124	124	124	62	0	0
HPP6	186	186	124	0	0	0	0	0	0	0
No. of time met p.p.	0	1	1	1	1	1	1	1	1	1
MPP1	168	220*	220*	223*	218*	221*	217*	155	117	0
MPP2	189	149	62	0	2	5	10	10	23	0
MPP3	190	176	158	0	51	20	0	0	62	62
MPP4	224*	225*	223*	220*	219*	217*	216*	217*	216*	162*
MPP5	108	138	147	40	12	99	1	1	0	0
MPP6	111	20	1	0	0	0	0	2	0	0
No. of time met p.p.	1	2	2	2	2	2	2	1	1	0
LPP1	86	66	89	20	27	27	62	0	0	0
LPP2	198*	236*	117*	119*	62	83	55	0	20	0
LPP3	94	104	87	118*	90	49	44	27	22	0
LPP4	122*	109*	114*	55	67	23	0	0	3	30
LPP5	98	142*	135*	125*	100	42	0	0	0	0
LPP6	197*	232*	197*	206*	203*	190*	155*	183*	138*	136*
No. of times met p.p.	3	4	4	4	1	1	1	1	1	1

Table 3. Period one mean contributions

Provision point	Mean	Standard deviation
LPP	132.5	51.76
MPP	165.0	46.60
HPP	154.3	35.89
No PP	123.0	46.20

Observation 2: In early periods, the "cheap rider" problem does not appear to put LPP and MPP groups at a relative disadvantage in meeting the provision point.

Periods 2, 3, and 4 are the periods of most frequent attainment of the provision point. Four of the seven successful groups faced a low provision point (LPP), two faced a medium provision point (MPP), only one faced a high provision point (HPP). In period 1, 18 of the 24 participants in LPP contributed *greater than or equal to* one-fourth of m^+. Only 12 of 24 in HPP contributed all 62 tokens. This suggests that the "cheap rider" problem is not differentially inducing LPP participants to contribute less than an equal-proportion share of the provision point. In fact, they do better than those persons in HPP. Thus, this individual data, unlike the aggregate data, tends to be more consistent with the assurance problem conjecture than with the focal point conjecture.

Table 4. Individual contributions: period 1

No. of tokens	No. of contributions LPP	MPP	HPP
$0 \le m_i \le 26$	6	6	9
$m_i = 27$	3	0	0
$28 \le m_i \le 53$	11	4	1
$m_i = 54$	0	9	0
$55 \le m_i \le 61$	1	3	2
$m_i = 62$	3	2	12

Observation 3: The level of the provision point is affecting individual decisions in period 1.

Table 4 categorizes individual period 1 decisions by provision point level. In comparing LPP and MPP, one observes a pronounced shift towards higher contributions with MPP. With HPP, there is a small increase in the incidence of very low contributions and a dramatic increase in the number of persons contributing all 62 of their tokens.

The above observations suggest that, in early periods, neither the assurance problem hypothesis nor the focal-point hypothesis fully captures the behavior of these participants. The provision points are affecting individual behavior, but the data do not seem to be fully consistent with either the high or low provision equilibrium. However, previous work has shown early period behavior in VCM to be very different than that which occurs after successive iteration. We turn now to a discussion of observations from later periods of the experiments.

Observation 4: With some interesting exceptions, as the experiment progressed contributions tended to collapse. In general, by period 10 it is the assurance problem conjecture and not the focal point conjecture which best describes the data.

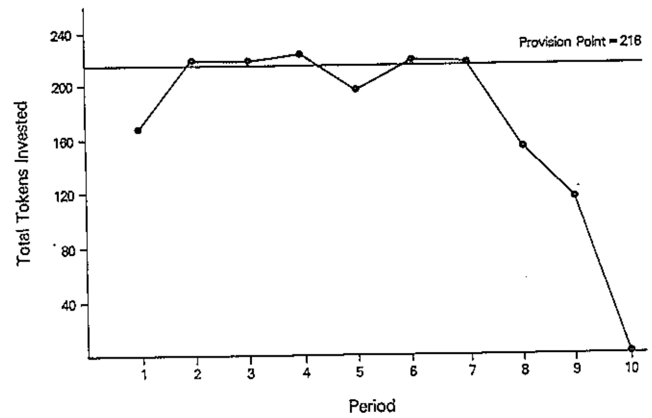

Figure 2. Example of a collapse in contributions: "medium" provision point experiment

One of the six HPP experimental groups succeeds in obtaining full contribution in periods 2 through 10. One of the six LPP groups exceeds the provision point for all ten periods. None of the MPP experimental groups succeeds for ten periods, although one did succeed for nine periods and maintained large contributions in period ten. Although 3 of 18 experiments is a small proportion, it should be emphasized that these three groups produced the public good at levels which we have *never* before observed with similar parameters but no provision point. On the other hand, it is not unfair to describe the contribution levels of other groups as "dropping like a rock" after some initial periods of significant contributions. An interesting point to note is that it is *not* just those groups which never reach the provision point which collapse. Figure 2 displays the data of one MPP experiment which met the provision point for periods 2–7 and then collapsed. Referring to Figure 1, it appears that HPP experiments are particularly susceptible to an early collapse to virtually zero contribution. Both the frequency of the attainment of the zero-contribution equilibrium and the vulnerability of the HPP are consistent with the assurance problem conjecture.

In summary, when compared with a non-provision point environment, an attempt to improve the performance of VCM by adding a provision point appears to have some interesting results. With some small probability, it can succeed in calling forth substantially greater levels of contribution. However, in the large majority of cases, it does not succeed and probably makes matters worse. (In the tenth period, 12 of the 18 provision point experiments were at precisely zero contribution, compared with 2 of the 7 without a provision point.) Thus, the failure of VCM as a mechanism for public goods provision does *not* require an underlying dominant strategy (or "free-riding") environment.[4]

4. A modification of the provision point environment

The results reported here suggest that it is not dominance *per se* which leads to underprovision of public goods. This suggestion is consistent with the results in Isaac and Walker (1988a), which showed that change in marginal returns can substantially increase provision even when zero contribution remains a single period dominant strategy. Thus, it is at least possible that the decay in contributions in VCM could be solved by some other institutional alteration in the underlying institutions and/or incentive structure. One such possibility is a change in the payoff structure if the public good is not provided. Schmidtz (1987) has proposed an institution known as the conditionally binding assurance contract which combines a provision point feature with a feature that contributions are returned if the provision point is not met. Our mechanism does not provide for explicit contracting, but it is possible to add a money-back guarantee. Dawes et al. (1986) found no significant improvement in contributions with the addition of a money-back guarantee. However, their decision environment was somewhat different than ours. Participants faced a one-time binary choice. Their rates of contribution (58 percent) *without* the money-back guarantee look more like our early-period results and do not match the decay we found in later periods. Furthermore, unlike our experiments, aggregate contributions in excess of the provision point produce no additional payoff. Bagnoli and McKee (1987) report that a combined provision point, money-back guarantee institution does a good job of eliciting efficient provision, although they do not report experiments lacking a money-back guarantee for comparison purposes and also have other design differences when compared with our experiments.[5]

We report here the results of 18 experiments in which the combination of a provision point and a money-back guarantee is evaluated. The experimental design is identical to the experiments described in previous sections. Six experiments were conducted with a provision point of 248 tokens (high provision point), six with 216 tokens (medium provision point), and six with 108 tokens (low provision point). In each experiment, participants were told that they had a "money-back guarantee" if the provision point was not obtained; any tokens which they had contributed to the public good ("invested in the group exchange") would be refunded as if they had been invested in the individual exchange.

The game-theoretic structure of the decision changes with the addition of the money-back feature. With the high provision point, full contribution to the group exchange is a (weakly) dominant strategy. On the other hand, any vector (m_1, m_2, m_3, m_4) such that for any two or more individuals m_i does not equal 62 tokens is an equilibrium, but not a perfect equilibrium.[6] For the medium and low provision points, there are no dominant strategies and "cheap riding" is again a possibility.

Table 5. Total investment in group exchange. 18 Design II (money-back) experiments

	Period									
Experiment	1	2	3	4	5	6	7	8	9	10
HPP1	186	155	176	182	123	174	246	210	175	98
HPP2	248*	248*	248*	248*	248*	248*	248*	248*	248*	248*
HPP3	246	218	177	179	214	248*	248*	248*	248*	248*
HPP4	248*	248*	247	248*	248*	248*	248*	248*	248*	248*
HPP5	248*	248*	248*	248*	248*	248*	248*	248*	248*	248*
HPP6	105	139	134	62	186	155	142	135	134	174
No. of times met p.p.	3	3	2	3	3	4	4	4	4	4
MPP1	230*	213	233*	229*	224*	225*	224*	224*	213	223*
MPP2	224*	216*	208	213	218*	216*	196	213	220*	221*
MPP3	220*	198	172	191	184	191	208	210	178	178
MPP4	211	217*	204	205	211	219*	217*	215	153	217*
MPP5	202	227*	202	200	219*	212	218*	227*	207	210
MPP6	248*	248*	248*	248*	248*	248*	248*	248*	226*	201
No. of times met p.p.	4	4	2	2	4	4	4	3	2	3
LPP1	154*	107	120*	111*	101	96	88	94	96	94
LPP2	142*	142*	117*	156*	127*	94	67	40	39	94
LPP3	209*	184*	110*	65	206*	122*	60	73	110*	76
LPP4	159*	132*	74	93	107	119*	106	106	110*	102
LPP5	94	106	78	144*	70	120*	40	28	62	32
LPP6	191*	120*	154*	125*	102	135*	61	119*	83	74
No. of times met p.p.	5	4	4	4	2	4	0	1	2	0

The results of the 18 experiments are summarized in Table 5 and in Figures 3, 4 and 5. The table lists each individual experiment and the total number of tokens contributed. Those periods marked with a "*" are ones in which the group met its provision point. The three figures compare mean total contributions to the public good with and without the money-back feature in each of the three provision point levels.

Observation 5: The addition of a money-back guarantee feature dramatically improves the provision of the public good in the high and medium provision point environments.

The ameliorative effect of the money-back provision is obvious in the high provision point environment. In the simple provision point experiments, only one of six groups was successful in stabilizing at the provision point; in these experiments, four out of six do so. Furthermore, even in the two high provision point experiments that do not stabilize at the optimal level, total contributions are non-trivial throughout. This reflects the fact that even in those two experiments where one or two people did not figure out the dominant strategy, one or more of the others in the experiment maintained contributions at the level of 62 tokens. (Overall, 18 of 24 subjects in high provision point experiments contributed 62 tokens in the final period.)

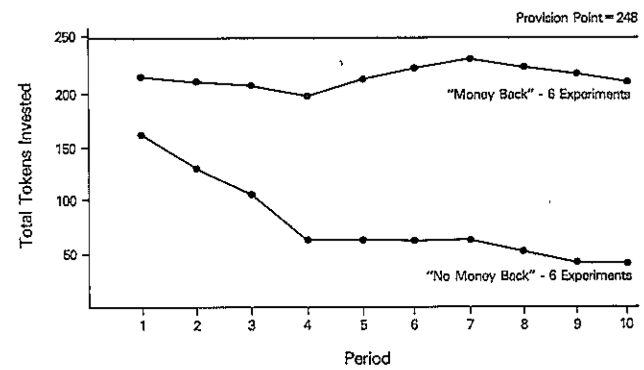

Figure 3. Mean number of tokens contributed: "high" provision point

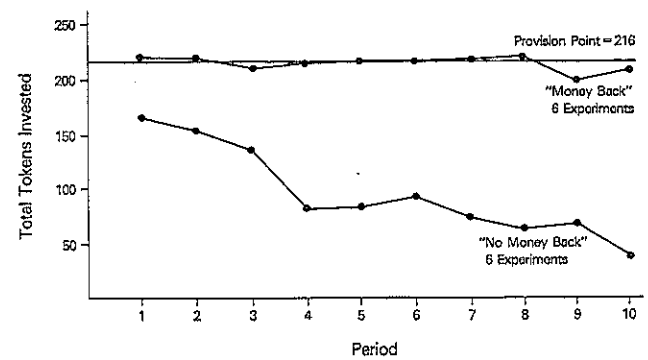

Figure 4. Mean number of tokens contributed: "medium" provision point

The money-back feature also made a significant difference in the medium provision point environment. Three groups were at the provision point in the last period and a fourth maintained provision for periods one through nine. Nevertheless, the ability of groups to stabilize at or above the provision point in these experiments is spotty when compared with the high provision point experiments.

In the low provision point environment, the money-back provision also ap-

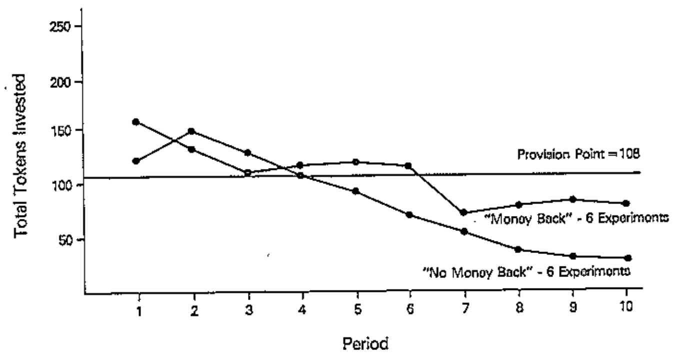

Figure 5. Mean number of tokens contributed: "low" provision point

pears to have made a difference in the early periods. In the first period, five of six groups met the provision point, compared with three of six without. However, *none* of the groups succeeded in period ten.

At least in the early periods, the increases in the levels of contribution compared with the no money-back experiments appear to derive from a generalized shift towards higher contributions rather than from increasing the success of the provision point as a focal point. In Table 6 we examine the period 1 individual decisions, as we did in Table 4, but in Table 6 we compare the money-back with the no money-back observations. Notice that in both LPP and MPP, there is an increase in frequency of contributions above the focal point category (one-fourth of the respective provision point). In fact, the frequency of contributions precisely at one quarter of the provision point actually declines in both LPP and MPP. Perhaps, on the other hand, the focal point characteristic of the provision point becomes potentially attractive, but early-period decisions "overshoot" the equilibrium level. If the focal point hypothesis is to succeed, this "overshooting" must be followed by a decrease in contributions until the aggregate is at (or at least "near") the focal point (equilibrium) level. But who should decrease? That question together with the mixed results from MPP groups and the almost complete failure of the LPP groups to stabilize at or above the provision point lead directly to our sixth observation:

Observation 6: Even with the money-back guarantee, cheap riding is still a problem in the medium and low provision point experiments.

An illustrative example is provided in Table 7, in which the individual decisions from the fourth medium provision point experiment are presented. Notice that in period 2, for example, the provision point is met with *one token* to spare. Nevertheless, the *distribution* of contributions is very uneven, ranging from 38 to 62 tokens. (Recall that participants are not informed of the distribution of the total investment.) In period 3, subject one, who had been a large contributor in period 2, reduced his or her contribution by *eight tokens* to 54 (which happens to be one fourth of the provision point). This group reached or exceeded the provision point in periods 2, 6, 7, and 10.

Table 6. Individual contributions: Period 1. A comparison of Design I and Design II

	No. of contributors					
	LPP		MPP		HPP	
No. of tokens	no–mb	mb	no–mb	mb	no–mb	mb
$0 \le m_i \le 26$	6	6	6	0	9	2
$m_i = 27$	3	0	0	0	0	0
$28 \le m_i \le 53$	11	10	4	5	1	3
$m_i = 54$	0	0	9	5	0	0
$55 \le m_i \le 61$	1	0	3	5	2	1
$m_i = 62$	3	8	2	9	12	18

"no–mb" = Design I (no-money-back).
"mb" = Design II (money-back).

Table 7. Individual contributions from experiment MPP 4

	Period									
Person	1	2	3	4	5	6	7	8	9	10
1	54	62	54	54	57	57	57	57	57	57
2	55	55	54	54	54	54	54	54	54	54
3	40	38	34	35	38	46	44	42	42	44
4	62	62	62	62	62	62	62	62	0	62

5. Concluding comments

The voluntary contributions mechanism has been demonstrated in prior research to be inherently susceptible to inefficient underprovision of public goods. Much of this research has been in the context of free-rider problem in which noncontribution was a dominant strategy equilibrium. In our Design I experiments, we have shown that this problem goes beyond the dominant strategy environment. Specifically, the "assurance problem" environment is characterized by a destruction of the dominant strategy nature of underprovision and the replacement by multiple Nash equilibria. Nevertheless, the behavior we observed was a very small incidence of groups obtaining the more efficient equilibria and a large incidence of decay to the very low levels of contributions. For the groups that decayed, the pattern was similar to that observed in the free-riding (dominant strategy) environment. Thus, we establish that the decay phenomenon is not caused solely by subjects learning a dominant strategy to free ride. This leads to a pessimistic conclusion that the voluntary contributions mechanism can significantly underprovide public goods in a much broader category than had been established by the dominant strategy experiments.

A further institutional modification involves combining a provision point with a money-back guarantee. Such an institution was examined in our Design II experiments. The results showed that this combined institution *did* have an ameliorative effect in promoting provision of the public good, although it was still subject to problems when, in the low and medium provision point levels, there were multiple equilibria supporting the provision point. We called this problem "cheap riding."

One obvious next step in this line of research is to examine the effectiveness of the combined institution (which is related to Schmidtz's conditionally binding assurance contract) in different economic environments and with slightly different operational characteristics. One such perturbation would involve the importance of the full money-back feature. In particular, suppose contributions were (i) only partly refundable; or (ii) refunded much later, without interest, so that they were not fully refunded in present value terms; or (iii) supposedly refundable, but with the credibility of the refund unsure so that the refund becomes a risky prospect. Would the institution continue to produce the optimistic results noted here? We report the results of two pilot experiments which address this issue. These two experiments used the high provision point and were conducted, with one exception, in the same manner as the Design II experiments described above. The one difference in the experimental design was that subjects were offered as a money-back guarantee only *one-half* of the rate of the investment in the individual exchange. The results of these experiments are reported in Table 8. The remarkable fact is that, by period 10, both experiments had contributions collapse to zero. Thus, the partial money-back produces behavior that looks like the results when there is no money-back guarantee at all. This suggests that a money-back guarantee (as in a conditionally binding assurance contract) must be complete and credible for it to be successful in promoting the provision of public goods in an environment characterized by the assurance problem.

Table 8. Two HPP experiments with one-half money-back. Total investment in group exchange

	Period									
	1	2	3	4	5	6	7	8	9	10
Experiment 1	64	62	62	0	2	0	62	0	0	0
Experiment 2	248	248	248	236	186	186	62	62	0	0

Notes

1. Notice that the environment is not technically one of complete information because the fact that opportunity costs of contribution (return from the private exchange) and token endowment are the same is not specified publicly. (But see Isaac and Walker, 1988b, for some evidence that participants seem to act as if they know the symmetry.) Nevertheless, it should be emphasized that the instructions tell the subjects that the return from the group exchange is identical for everyone.
2. Throughout the development of the hypotheses, we concentrate on the complete information, single-shot, pure strategy equilibria. In our previous papers, the single-shot dominant strategy (free-riding) equilibrium "unraveled" backwards from period 10 to a unique multiple period, complete information Nash equilibrium (zero contributions in each period). In the designs of this paper, there are multiple single-shot Nash equilibria. Backward unraveling from period 10 does not have a unique base upon which to build. Replication of the single shot Nash equilibria can be supported as multiple-period Nash. Thus, the critical distinction of these experiments, the multiplicity of Nash equilibria, is not lost if one looks at finitely many multiple periods. As with the previous dominant strategy designs, there has been some theoretical work on finite, multiple-period incomplete information equilibria. This literature primarily addresses existence and qualitative predictions and does not, to our knowledge, generate quantitative predictions for our current experiments. In addition, these models typically do not match precisely the conditions of our experiments. A relevant reference is that of Fundenberg and Maskin (1986).
3. To see this, let (m_1, m_2, m_3, m_4) be any vector of contributions such that each contribution is less than or equal to 62 tokens and m_i = 216. If any one contribution is increased by any number of tokens, K, then that participant lowers his total earnings for that period by 0.7 × K cents. Likewise, if any m_i is lowered by D tokens, then the profits to that participant change by [D−64.8] cents. Because D must be less than or equal to 62, such a reduction makes that participant worse off. The most advantageous equilibrium for any one person is one such as (62, 62, 62, 30). However, even the over-providers are earning 64.8 cents.
4. A reviewer of the paper suggested that these designs could be ones in which the role of subject experience is more dramatic than in our previous experiments. The argument goes as follows: Our previous experiments indicated that experience provided for faster decay to a unique equilibrium. The current designs are characterized by multiple equilibria. Perhaps in these designs the effect is not just a matter of speed but rather of which equilibrium is obtained. Specifically, perhaps inexperienced subjects, never having seen contributions decay, would be more likely to obtain the Pareto superior equilibria. We thought that this was an excellent comment, and while not having the resources to completely replicate the design, we conducted five additional experiments: three with HPP; two with LPP. None of the HPP groups ever achieved the provision point in any period. One LPP group succeeded only in periods 1 and 3, and then collpased to zero contribution. The other LPP group succeeded in eight periods (1 through 7 and

9) but failed in periods 8 and 10. Thus we conclude that this inexperience was not in and of itself sufficient to alter our major results. Whether it would have some marginal effect or interact in some unsuspected way with other elements of our design can only be established through a more exhaustive replication of the designs.

5. For example, Bagnoli and McKee, like Dawes, et al., have a design with no additional benefit from exceeding the provision point. Also, Bagnoli and McKee explicitly make the initial wealth distribution common knowledge. In addition, they used inexperienced subjects.
6. To see this, consider as an example the vector of contributions (62, 62, 10, 10). Under the rules of the institution, the full provision point is not met and each person obtains 62 cents. This is an equilibrium vector in the sense that no one of the players can, by unilaterally altering a decision, improve upon his private payoff. However, this equilibrium is not trembling hand perfect (in the sense of Selten, 1975) with respect to small probabilities that the equilibrium (62, 62, 62, 62) will obtain.

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