ELSEVIER

Journal of Public Economics 72 (1999) 455–470

JOURNAL OF PUBLIC ECONOMICS

Voluntary revelation of the demand for public goods using a provision point mechanism

Daniel Rondeau[a], William D. Schulze[b,*], Gregory L. Poe[b]

[a]*Department of Economics, Cornell University, Ithaca, NY, 14853, USA*
[b]*Department of Agricultural, Resource, and Managerial Economics, Cornell University, Ithaca, NY 14853, USA*

Received 31 March 1997; received in revised form 31 December 1997; accepted 30 June 1998

Abstract

A one-shot provision point mechanism with money-back guarantee and proportional rebate of excess contributions is tested in an induced value framework and in experimental environments chosen to mimic field conditions. The results show that this relatively simple mechanism is empirically demand revealing in the aggregate when used with large groups of students who have heterogenous valuations for the public good. Approximately demand revealing behavior was obtained under three alternative information conditions. These results are an important step in the design of a mechanism simple enough to allow field applications, but capable of efficiently providing public goods through voluntary contributions.

Keywords: Public goods; Voluntary contributions; Provision point; Experiments; Information; Group size

JEL classification: H41; C92

1. Introduction

Benevolent organizations, clubs, associations and at times even governments and industry rely on citizen action and voluntary monetary contributions to provide a wide variety of public goods. Unfortunately, standard theoretical models of

*Corresponding author. Fax: 607-255-9611.
E-mail address: wds3@cornell.edu (W.D. Schulze)

0047-2727/99/$ – see front matter
PII: S0047-2727(98)00104-2

voluntary public goods provision make strong predictions of under-contribution by individuals. Although individuals do contribute voluntarily toward the provision of public goods, the evidence provided by two decades of experimental research clearly supports the prediction of under-contribution (Ledyard, 1995; Davis and Holt, 1993). Relying on funding mechanisms that inaccurately reflect contributors' preferences suggests that socially desirable public goods are produced at sub-optimal levels and underscores the need for a contribution mechanism capable of revealing the demand for public goods in natural conditions.

Such a mechanism has thus far eluded researchers. Some public goods mechanisms such as the Groves–Ledyard (Groves and Ledyard, 1977) and Smith Auction (Smith, 1979, 1980; Coursey and Smith, 1984; Harstad and Marrese, 1982) have been shown to induce optimal production of public goods in laboratory settings after a number of rounds of repeated play. Unfortunately, these are far too complex and impractical for implementation in field conditions where pragmatism dictates the use of a simply understood one-shot mechanism (Davis and Holt, 1993; Alston and Nowell, 1996). An alternative mechanism, the Voluntary Contributions Mechanism (VCM) has the simplicity required for field applications but consistently produces contribution levels 40 to 60% below the optimum[1].

In this paper, we report the results of a series of laboratory experiments in which we explore the performance of a one-shot provision point mechanism (PPM) with money back guarantee (MBG) and a proportional rebate of excess contributions (PR) applied in experimental conditions that attempt to replicate field circumstances. These include the use of large groups of non-economics students and incomplete information.

With this mechanism, a public good of pre-determined size is provided only if the sum of contributions equals or exceeds its cost (the provision point). If contributions fall short of costs, they are completely refunded (the money back guarantee) whereas if they exceed costs, the excess is returned to each contributor proportionally to the share of their individual contribution in the total amount contributed (the proportional rebate). As we indicate in the next section, the PPM has been shown to increase contributions but has fallen short of inducing demand revelation. Yet, because of the design of previous experiments, little can be said with certainty about the performance of this mechanism in environments resembling plausible field conditions where a single shot is required and a potentially large number of individuals with heterogenous values can benefit from the provision of a public good.

The central objective of our research is therefore to test the performance of the PPM with a MBG and a PR in experimental environments that mimic key features and constraints encountered in the field. The provision point framework enables us to induce well defined individual values for a discrete public good, thus providing a basis to measure how variations in the environment affect contributions. In

[1]See Ledyard (1995) for a thorough survey of experimental research on the Voluntary Contributions Mechanism.

particular, we investigate the impact of group size and incomplete information on the proportion of induced value revealed by subjects. Group size has been shown to have positive effects on contributions with other public goods mechanisms (Isaac et al., 1994; Rose et al., 1997) while limited evidence exists on the effect of incomplete information in PPM experiments (Marks and Croson, forthcoming). Our results show that, regardless of the information condition in which the mechanism is tested, large groups of non-business students given heterogenous values provide an aggregate amount of contributions approximately equal to their induced demand for the public good.

After a brief review of past findings, we present two sets of experiments in which we examine in turn the effects of group size and variations in information conditions on the proportion of induced demand revealed by participants. Concluding remarks follow.

2. The provision point mechanism

In a typical provision point experiment, participants are part of a group of N individuals taking part in a number of decision rounds. At the beginning of a round, each person in the group is given an initial balance of money (denoted by the letter I) and must decide how much of this money to keep and how much to allocate to a group fund (B_i, where the subscript indexes the individual's contribution). If the mechanism includes a MBG (first tested in similar experiments by Isaac et al., 1989) and the sum of contributions is below the provision point (PP), contributions are fully refunded and individual earnings are equal to the initial balance. Alternatively, if the group sum of bids equals or exceeds the PP, the group fund yields a return and individual's earnings for the round are the sum of the initial balance minus her contribution, plus a personal return from the investment fund (the induced value, V_i), plus a payment according to the rebate rule implemented. The proportional rebate rule used in this paper was first proposed by Smith (1980) as part of the Smith public good auction and was recently studied by Marks and Croson (1998) in a PPM setting. Under this rule, contributions in excess of the PP are returned to individuals in proportion to the share of their personal contribution relative to the total received. For example, someone whose contribution amounts to 5% of total donations would receive a rebate equal to 5% of the amount of contributions in excess of the PP. Hence, individual i's earnings (E_i) are given algebraically by

$$E_i = \begin{cases} I & \text{if } \sum_{j=1}^{N} B_j < \text{PP} \\ I - B_i + V_i + \dfrac{B_i}{\sum_{j=1}^{N} B_j}\left(-\text{PP} + \sum_{j=1}^{N} B_j\right) & \text{if } \sum_{j=1}^{N} B_j \geq \text{PP} \end{cases}$$

In this context, a socially desirable public good is created by the experimenter if the sum of induced values is greater than the provision point. This public good is efficiently provided if subjects make aggregate contributions that equal or exceed the provision point. Therefore, aggregate demand revelation, if it can be achieved, would guarantee that all desirable public goods will always be provided and that the mechanism is perfectly efficient regardless of the PP and whether or not it is known by subjects.

Isaac et al. (1989); Suleiman and Rapoport (1992); Dawes et al. (1986) report that simply creating a threshold cost of provision had a significant positive impact on contributions compared to similar VCM treatments. This result is testimony to the power of a provision point since, in the absence of a MBG, failure to reach the provision threshold results in a loss of contributions by individuals. A MBG would therefore seem to be a desirable form of insurance against such losses. Significant increases in contributions have been reported by Isaac et al. (1989) in experiments where subjects were free to contribute any amount toward the provision of the public good and by Rapoport and Eshed–Levy (1989) in experiments where participants could contribute a fixed amount or nothing at all. In contrast, Dawes et al. (1986) found no improvements in contribution rates after adding a MBG in a similar binary decision environment.

Adding a rebate rule is another form of insurance guaranteeing that contributions in excess of the PP will not be lost by the group. Marks and Croson (1998) investigated the effects of alternative rebate rules in PPM experiments with MBG. They report that implementing the PR rule or using excess contributions to increase the scope of the public good both improved contributions. Here, we chose to implement the PR rule because it has a positive effect on contributions and, compared to the increased scope rule, it fixes the cost and benefits of the public good, providing experimental control over the subjects' values.

The full information game theoretic predictions for the PPM with MBG was derived by Bagnoli and Lipman (1989) and is further discussed by Marks and Croson (1998) for the case where a PR rule is added to the mechanism. In this game, any combination of individually rational contributions summing exactly to the provision point is an efficient Nash outcome[2]. It should be clear that when the benefit–cost ratio of the public good is greater than one, aggregate demand revelation is not a Nash equilibrium since any individual who contributed a

[2]Assuming that players are only motivated by their own gains, a contribution is individually rational if it does not exceed the players' value for the public good. This game also has a large set of inefficient equilibria. An inefficient equilibria is any vector of individual contributions where

$$\sum_{j=1}^{N} B_j < \mathrm{PP}; \text{ and 2) } \left(\mathrm{PP} - \sum_{j=1}^{N} B_j\right) > (V_i - B_i) \forall i \, .$$

That is, the sum of contributions is below the provision point and no individual can unilaterally increase his or her contribution to make the group reach the provision point while maintaining individual rationality.

positive amount would choose to unilaterally reduce the amount of such contribution given the chance (as long as the PP is still met). Hence, the PPM is not theoretically incentive compatible. Whether or not it is demand revealing is therefore a purely empirical question.

Bagnoli and McKee (1991) conducted full information provision point experiments with MBG using small groups of subjects who were given unequal values for the threshold public good. These subjects contributed on average 78.7% of their value in the first round of the game. In a simpler design, Cadsby and Maynes, 1998a,b) used a PPM without MBG or rebate and gave equal endowments and valuations to all subjects. In the first round of separate experiments, economics and business students contributed 60.6% of their true demand, nurses revealed 85%, groups of male-only students contributed 40.2% and female-only students contributed 56%. Finally, in a study of alternative rebate rules, Marks and Croson (1998) obtained aggregate contributions averaging 63.7% of induced value in the first rounds of treatments with a MBG and PR[3].

With contribution levels ranging from 40 to 85% of induced demand, variants of the PPM yield some improvements over the 40 to 60% of optimal contributions usually obtained with the VCM but it leaves a substantial gap for desirable projects to go unfunded. However, the laboratory environments constructed for earlier tests of the PPM differ from plausible field conditions in many respects. Hence, we seek to analyze the performance of the PPM with MBG and PR in experimental environments that more closely resemble field conditions.

The key environmental conditions that set our experiments apart from previous research are related to group size, repetition of play, subject pool used, distribution of benefits from the public good, and information available to participants. Whereas previous research was conducted with small groups of 5 to 12 subjects, we test the performance of the mechanism in groups of up to 50 subjects. In an equally important departure from prior research, we limit our experiments (with the exception of a control group) to a single round of decision making. This approach removes any possibility of strategic behavior that may exist in early rounds of repeated games. In the experiments reported in this paper, we assign subjects to one of several payoff conditions. Such heterogenous values are a characteristic of field conditions that allows us to induce a controlled, downward sloping demand curve for the public good. Of all experiments previously

[3]Rapoport and Suleiman (1993); Asch et al. (1993); Marks and Croson (forthcoming); Croson and Marks (1996) have also conducted interesting provision point experiments. Unfortunately, individuals in these studies were given initial balances lower than their value for the public good. Hence, they faced an income constraint that did not allow them to reveal their true demand and precludes an unbiased analysis of demand revelation in these experiments. Similarly, Isaac et al. (1989) added a provision point and a money back guarantee to the VCM environment of Isaac et al. (1984). The mechanism used an extended benefit rule whereby contributions beyond the provision point increase the scope of, and hence the benefits from the public good. Additional benefits beyond the provision point eliminate the well defined demand against which to assess demand revelation performance.

conducted, only Bagnoli and McKee's design combined heterogenous values with a sufficient money endowment for subjects to reveal their demand for the public good. Finally, for our second set of experiments, we recruited subjects with a more diverse background than the economics and business students traditionally used in experimental economics. This sets aside questions regarding the possible effects of economics training on behavior in these treatments. Of the research cited earlier, only Cadsby and Maynes have systematically chosen non-economics students in their treatment with nurses.

The resulting combination of environmental features differs substantially from any laboratory setting previously assembled for studying the PPM. This basic environment will be modified to test the effects of group size and incomplete information on contribution levels.

3. The effect of group-size on contributions

Isaac et al. (1994) found that individuals in groups of 40 and 100 individuals contributed a significantly larger proportion of their endowment to a VCM public good than did subjects in groups of 4 and 10. The only other large group ($n=100$) experiment we are aware of was conducted as part of our own research program but in a different context. In Rose et al. (1997), we report that a PPM with MBG where subjects could only contribute a fixed amount (or not at all) produced aggregate results consistent with demand revelation: on average, individuals with values higher than the fixed amount contributed, while those with values lower did not. However, because of the constrained contribution level, questions remain as to whether group size effects carry over to the PPM with continuous contributions, MBG and PR. We address this question first by comparing contribution levels in groups of six and fifty students.

3.1. Design

Four ''pen and paper'' experiments were conducted with lower division Cornell University students. The first three of these were small group control experiments while the fourth was carried out with a large number of subjects. For each of the small group experiments, six volunteer students who had never participated in economics experiments were recruited from an introductory economics class. It was emphasized in recruiting students that no knowledge of economics was required to participate.

At the beginning of the session, subjects read instructions describing the experiment and their task but were not given complete information about the parameters of the game[4]. They knew the size of the group and that all participants

[4]Instructions are available from the authors.

had an equal endowment of 500 experimental cents. They also knew their potential private payoff from the public good. However, they were told that this payoff had been randomly selected but were not given any information about the distribution of values. They were only informed that other subjects may not have the same payoff. This feature mimics field conditions where individuals value public goods differently but are generally unaware of other people's values (Alston and Nowell, 1996).

The level of the provision point was not disclosed either. It was only announced that it had been randomly drawn from an unspecified distribution. Withholding information about the PP prevents subjects from making their contribution decision based on an ''equal cost share'' strategy (e.g. dividing the cost of the project equally among participants)[5] and may help raise contributions. Finally, participants in the small group experiments knew that the game would be repeated, but were not told how many times. For the purpose of this paper, however, we will only be interested in results from the first period since it is most comparable to the single shot large group experiment that follows[6].

Individual payoffs from the group fund, if the provision point was met or exceeded, were the randomly drawn numbers \$2.12, \$2.42, \$3.69, \$3.72, \$3.76 and \$3.90 experimental dollars, for total benefits (aggregate induced demand) from the public good of \$19.63. The randomly drawn provision point was \$7.53, creating a benefit–cost ratio of 2.6. Experimental earnings were exchanged at the rate of one dollar = \$0.25 (US).

The large group experiment was conducted with fifty students from a different undergraduate economics class. Rather than recruiting on a voluntary basis, all students in the class participated in the experiment[7]. This experiment was limited to a single period of play. The one-shot game better conforms to field conditions

[5]Share calculations are rarely possible in the field, except for club goods. The information condition where the group size is known but the PP is unknown has real life parallels. An example comes from the Niagara Mohawk Power Company which recently offered its 1.2 million residential customers a green choice program in which the final cost of the project was to be determined through competitive bidding (Rose et al., 1997).

[6]As in the one-shot application, subjects in the first period of a repeated game have no experience with the mechanism. However, repeated play may encourage signaling in early rounds, thereby increasing contributions in this treatment. If this were the case, the direction of the bias would make it more difficult to demonstrate that group size positively affects contribution levels. This approach is therefore conservative.

[7]All large group experiments reported in this paper have been conducted with entire classes of students. Conducting experiments with entire classes avoids the risk of self-selection bias inherent to the recruitment of volunteers. The experiments were conducted at the beginning of a regular class by a guest lecturer and his research assistants, none of whom had prior contacts with the students or would be involved in the students' grading. Participation was not mandatory and it was emphasized that the experiment was performed for research purposes only (although aggregate results would be reported at the end of the class) and that individual answers and earnings would remain strictly confidential. Finally, the regular instructor was not involved in conducting the experiment. We believe that these procedures reduce the possibility that expectational effects bias the data.

and allowed us to increase individual stakes fourfold by adjusting the exchange rate to one experimental dollar = $1 (US) (behavior should not be affected by such a monotonic transformation). The PP was scaled up to $62.75, an increase proportional to the change in the number of students in the group, but this change cannot affect the results since the PP remained unknown to subjects. The experiment was otherwise identical to the small group control experiments. The same six randomly drawn induced values were used and the information position of subjects was unchanged.

3.2. Results

We use several indicators to report the performance of the mechanism. However, we are particularly interested in the mean and median of B_i/V_i, the proportion of individual induced value contributed to the group fund. We will also pay a special attention to the ratio of aggregate demand revealed to aggregate demand induced ($\Sigma B_i/\Sigma V_i$).

Pooling the data from the three small group experiments we find that individuals contributed on average 64% of their induced value, with a median of 71.8%. The ratio of aggregate revealed demand to total induced demand is 66.7%. This ratio falls within the range of 40.2% to 85% reported in previous research. Thus, we feel comfortable that our design and instructions are comparable to earlier PPM experiments and provide an adequate basis of comparison for the results of the large group treatment. A summary of the results is presented in Table 1.

In contrast, participants in the large group experiment approximately revealed their demand for the public good. The mean and median proportion of value contributed by individuals to the group fund were respectively 110% and 104%. The mean of 110% is not statistically different from 100% at the 5% significance

Table 1
Summary data: small and large group comparison

Experiment ID	Small groups (Pooled data)	Large group
Number of subjects (N)	18	50
Mean V_i (cents)	327	325.8
Mean contribution (cents)	218.1 *	349.0
(SD)	(128.2)	(135.5)
Median contribution (cents)	200	380
Mean B_i/V_i	64.4%**	110.0%***
(SD)	(32.1%)	(48.5%)
Median B_i/V_i	71.8%	104.0%***
Percentage of demand revealed	66.7%	107.1%

*Different from 300 at the 5% significance level.
**Different from 100% at the 5% significance level.
***Different from the small group result at the 5% significance level.

level ($t=1.459$). On the other hand, we reject the hypothesis that the mean from the large group is equal to the mean of 64% of value obtained in the small group experiments ($t=3.788$)[8]. Parallel tests on the medians confirm these results[9]. The medians of the small and large group experiments are significantly different from one another at the 5% significance level (Mann–Whitney $z=3.753$). A 95% confidence interval around the large group's median (Snedecor and Cochran, 1989) is bounded by 100.00% and 117.92%, clearly containing the value of 100% we would expect for a perfectly demand revealing mechanism. Hence, all tests support the conclusion that contribution levels in the large group experiment are different from those obtained from small groups, but not different from aggregate demand revelation. In the aggregate, the ratio of revealed to induced demand in the large group is 107%, a close approximation to demand revealing behavior.

Figs. 1 and 2 illustrate the results. In these figures, the bars represent individual induced values and are graphed in descending order to form the induced demand for the public good. Individual contributions are also ordered from high to low and plotted as a line to represent the revealed demand curve. These graphs vividly

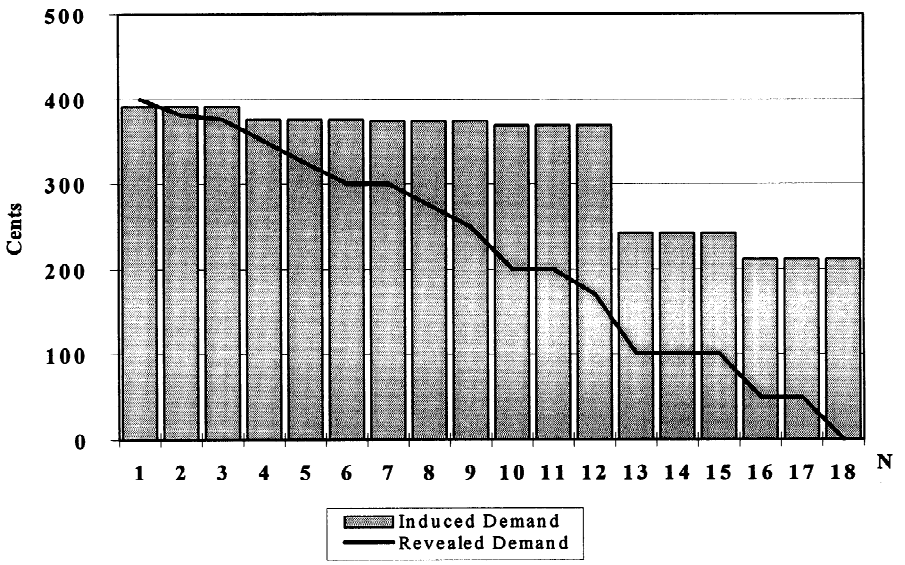

Fig. 1. Induced and revealed demand: small group experiments pooled.

[8]The difference is significant at the 5% confidence level. The degrees of freedom for this test were adjusted to 47 to account for the statistical inequality of variances in the small and large group data.

[9]Tests on means are biased by the fact that roughly a quarter of all individual contributions in the large group experiment appear to have been constrained by the initial endowment of $5. This truncates the distribution of contributions, restraining both the mean and variance of the individual bid to value ratios. However, since the direction of the bias is to lower the difference between the means of the two experiments, we maintain that the difference would still hold in the absence of the endowment constraint. Tests on medians are not affected by the truncation of contributions.

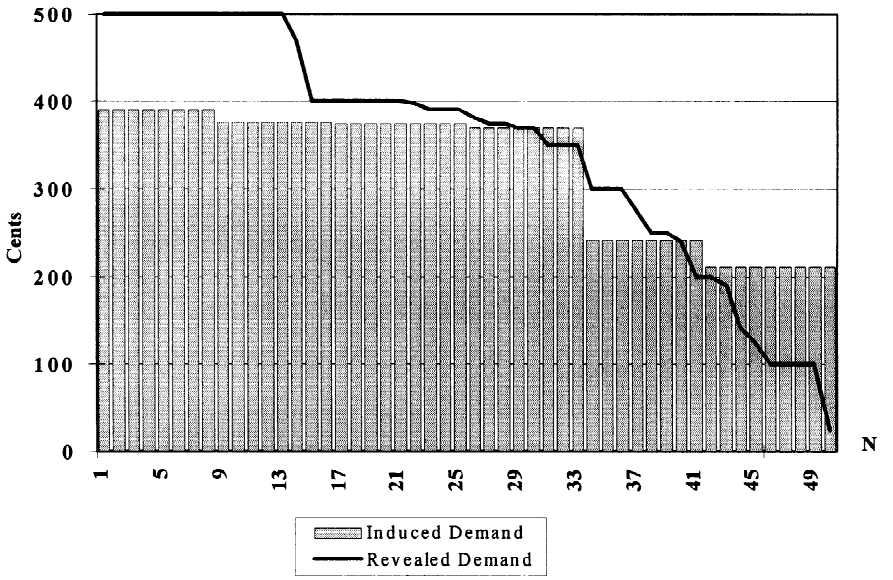

Fig. 2. Induced and revealed demand: large group experiment.

illustrate the upward shift in the revealed demand curve obtained in the large group experiment. The overbidding and capping of contributions in the large group experiment are also visible in the upper left hand corner of Fig. 2. These large bids roughly compensate for the cheap riding observable at the other end of the curve where induced demand is above revealed demand.

While we attribute the increase in contributions primarily to group size, we must note that other design features did not remain constant between treatments and may be responsible for the observed differences. Subjects were from different classes, participants in the small group experiments were volunteers whereas the large group treatment was conducted with an entire class, and the results reported for small groups are the donations in the first round of a repeated game as opposed to a single application of the mechanism. Notwithstanding these caveats, the data from these experiments demonstrate that it is possible to induce large groups to voluntarily reveal their aggregate demand for public goods with a relatively simple mechanism. Next, we set out to replicate these results and test the effect of alternative information structures on subject behavior.

4. The role of incomplete information in the provision point mechanism

The objectives pursued with this set of experiments are (1) to replicate with non-economics students the results obtained in our first large group experiment

and (2) to test whether alternative information conditions affect contribution levels. Specifically, we follow Bagnoli and Lipman and conjecture that when the number of subjects and the value of the PP are both known, subjects may show a greater tendency to choose a contribution level representing equal cost shares (PP/N, the symmetric Nash equilibrium). In a test of this conjecture, Bagnoli and McKee (1991) found empirical evidence of cost-sharing in full information experiments. Withholding information about the value of PP or N removes this focal point and may encourage demand revelation by forcing individuals to formulate a contribution strategy more strongly based on their private incentives rather than on the availability of a simple rule of thumb. This reasoning is similar to the Bohm (1972) argument that uncertainty about the cost of a public program puts ''voters'' in a situation in which incentives to using simple strategies leading to bias are absent[10]. Thus, we seek to explore the effect on contributions of removing information about the number of subjects and the level of the provision point.

4.1. Design

Three experiments were conducted with groups of 45 students enrolled in an introductory natural resources course. Approximately 5% of those students had previously taken an economics class. Subjects were endowed with an initial balance of 600 cents and randomly assigned to one of five induced values ranging from \$1.50 to \$4.50, in increments of \$0.75. The only difference between treatments was the information participants received about the number of subjects in their group and the level of the provision point. Subjects in group A were informed that 45 students in their group faced an investment cost of \$45. Subjects in group B only knew the number of students in the group, and members of group C were only informed about the value of the provision point[11]. Therefore, this

[10]Marks and Croson (forthcoming) found that withholding information about other subject's values for the public good to prevent subjects from calculating the proportional cost-share

$$\left(\mathrm{PP}^{*}V_i/\sum V_i\right)$$

had no significant effect on the tendency of groups to adopt Nash behavior. This design still allowed subjects to calculate the equal cost share (PP/N) which is of interest to Bagnoli and Lipman, Bagnoli and McKee and to us.

[11]Each of these information conditions corresponds to a plausible public good situation. Group A corresponds to the funding of a club good with known cost. An example of such a situation occurred when the nordic ski club in Boulder CO raised money to maintain a bankrupt ski area for the winter. Members of group B represent a community of known size raising money for a project subject to cost uncertainty akin to the Niagara Mohawk Power Company program alluded to in Footnote 3. The information condition faced by members of group C are similar to many public allocation problems. A land trust soliciting donations from the public for the purchase and conservation of a tract of land falls in this category.

experiment not only tests the focal point hypothesis but also evaluates the performance of the PPM in alternative situations relevant to field applications.

Our original instructions were edited to accommodate these changes. Subjects in incomplete information treatments were told that the number withheld from them was ''predetermined but unknown to you''. Since the group size was unknown in one group, all instructions contained two examples of the proportional rebate rule. These examples used groups of size 2 and 200, respectively. Subjects were told that these were the minimum and maximum possible number of students in a group since the enrollment for the class was 200[12]. With $n=45$ and PP=\$45, the focal point of \$1 is easily computed by subjects in group A and was deliberately set low enough to make the cost sharing strategy rational for all subjects (all induced values were above \$1).

4.2. Results

Table 2 summarizes the descriptive statistics for each treatment. The first notable result is that there is no significant difference in behavior across alternative information conditions. The average proportion of individual value revealed by subjects ranges from 103% for group B to 132% for group C. Group A, which had the information to calculate equal cost shares, falls between the two with an average of 110% of individual value revealed. Pair-wise means tests cannot detect significant differences between these values [$t_{\text{A vs. B}}=0.381$; $t_{\text{A vs. C}}=-0.970$; $t_{\text{B vs. C}}=-1.392$ (unequal variances)], and rank-sum tests comparing the median

Table 2
Summary data and comparison across information conditions

Experiment ID Information provided	A (N) yes; (PP) yes	B (N) yes; (PP) no	C (N) no; (PP) yes
Number of subjects (N)	45	45	45
Mean V_i (cents)	300	300	300
Mean contribution (cents)	288.9	285.6	337.7
(SD)	(221.2)	(190.3)	(210.8)
Median contribution (cents)	250	300	350
Mean B_i/V_i	110.5%	103.2%	132.2%
(SD)	(99.2%)	(83.5%)	(112.0%)
Median B_i/V_i	86.1%	93.3%	100.0%
Percentage of demand revealed	96.3%	95.2%	112.6%

[12]Actual attendance for the class was 149. The 14 students who could not be accommodated in groups A, B, or C were put in a group D where both PP and N were unknown so that everyone in the classroom could participate in an experiment. We do not report the data from Group D since most students in this group were not present for opening remarks announcing the experiment and the general procedures that would be followed.

bid to value ratios of 86%, 93% and 100% also fail to indicate differences between the three treatments ($Z_{\text{A vs. B}}=0.073$; $Z_{\text{A vs. C}}=0.892$; $Z_{\text{B vs. C}}=1.00$).

The number of \$1 bids for groups A, B and C is respectively 7, 3 and 4. Hence, bids at the focal point are more frequent in group A. However, in tests of proportionality comparing group A to B and C, we cannot reject the null that the frequencies are equal ($p_{\text{A vs. B}}=0.180$; $p_{\text{A vs. C}}=0.334$). Based on this evidence, we conclude that the availability of information on N and PP did not create meaningful incentives to adopt a simple cost sharing strategy.

The most important finding of this paper is that, in large group situations, the ability of the provision point mechanism with MBG and PR to reveal aggregate demand appears robust to changes in experimental parameters, subject type and information provided to participants. The individual contribution to value ratios of 103%, 110% and 132% found for groups A, B and C are not different from 100% at the 5% significance level. Similarly, each of the medians, at 86%, 93% and 100% of induced value, generates a 95% confidence interval that includes 100%. We also note that the mean bids of \$2.89 ($t=0.332$), \$2.86 ($t=0.494$) and \$3.38 ($t=1.208$) do not statistically differ from the mean induced value of \$3.00. Finally, 95% confidence intervals around each of the median contributions of \$2.50, \$3.00 and \$3.50 include the value of \$3 consistent with a mechanism that, overall, produces demand revelation.

The total demand revealed by the three groups are 96%, 95% and 112% of total

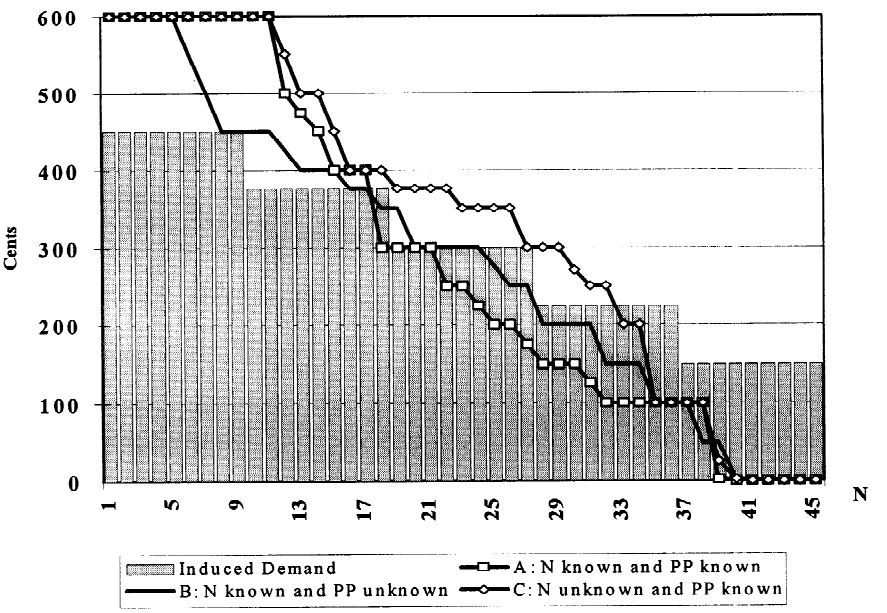

Fig. 3. Induced and revealed demand: effects of information experiments.

induced value. These ratios are comparable to the ratio of 107% found in our first large group experiment. Hence, our initial large group results were replicated in a total of three different information conditions, with a modified vector of induced values, and using non-business students. Fig. 3 illustrates the results. As we previously reported, overbidding by some subjects essentially offsets the cheap-riding of others in all treatments. While the slopes of the revealed demand curves are poor indicators of true demand, the means and medians are accurate and can be used to infer the aggregate benefits of the public good. Since a number of subjects still appear to have been constrained by their endowment, median statistics should be given more weight than means.

5. Conclusion

Using large groups in an induced value framework, we have shown that the provision point mechanism with money-back guarantee and proportional rebate of excess contributions can closely approximate demand revelation. The mean and median statistics for both, the absolute individual contributions and the proportion of induced value revealed were all statistically consistent with demand revealing behavior. To our knowledge, it is the first time that a simple one-shot public goods mechanism that allows a wide range of donation levels has elicited voluntary contributions approximately equal to the true value of a public good.

Overall, the cheap-riding of some subjects was compensated by the over-contributions of others in all four large group experiments presented in this paper. The fact that some subjects contributed amounts above their induced value appears to be irrational and suggests that additional research designed to test individual motives is required. It is possible that subjects have altruistic motives that cannot be directly controlled for in the laboratory. Some individuals may also erroneously interpret the MBG and PR as providing an insurance that earnings cannot be less than their initial endowment or that by contributing a large amount, it is possible to capture a larger part of contributions in excess of the PP. Palfrey and Prisbrey (1997) have recently suggested that, indeed, high contribution levels in early rounds of public goods (VCM) experiments can in part be explained by subject errors, but they also present evidence of the existence of a positive ''warm glow'' associated with the simple act of contributing toward the provision of a public good.

The provision point mechanism with money-back guarantee and proportional rebate is simple enough to provide hope that similar results can be replicated under field conditions. Yet, the failure of the same mechanism to reveal demand in prior research and in our own small group trials suggests that the key to fully understand the PPM resides not so much in the mechanism itself as in the environment in which it is applied. Some of the findings of this research point to group size as a determinant factor affecting contributions. Nevertheless, several additional experi-

ments will be required before we can adequately understand how group size and other factors such as subject background, recruitment or self-selection, altruism or warm-glow affect the performance of the PPM, and assess its capacity to efficiently provide public goods in real world situations.

Acknowledgements

We wish to extend our gratitude to Melanie Marks, Rachel Croson, Catherine Eckel, Leslie Marx, two anonymous reviewers and the editor for thoughtful comments. This research was supported by grant R824688 from the National Science Foundation and US Environmental Protection Agency and conducted while the first author was a doctoral fellow of the Social Sciences and Humanities Research Council of Canada. Additional financial support was provided by the College of Agriculture and Life Sciences–Cornell University. All opinions and errors remain our responsibility.

References

Alston, R.M., Nowell, C., 1996. Implementing the voluntary contribution game: a field experiment. Journal of Economic Behavior and Organization 31, 357–368.

Asch, P., Gigliotti, G.A., Polito, J.A., 1993. Free riding with discrete and continuous public goods: some experimental evidence. Public Choice 77, 293–305.

Bagnoli, M., Lipman, B., 1989. Provision of public goods: fully implementing the core through voluntary contributions. Review of Economic Studies 56, 583–601.

Bagnoli, M., McKee, M., 1991. Voluntary contributions games: efficient private provision of public goods. Economic Inquiry 29, 351–366.

Bohm, P., 1972. Estimating demand for public goods: an experiment. European Economic Review 3, 111–130.

Cadsby, C.B., Maynes, E., 1998a. Choosing between a socially efficient and a free-riding equilibrium: nurses versus economics and business students. Journal of Economic Behavior and Organization 37, pp. 183–192.

Cadsby, C.B., Maynes, E., 1998b. Gender and free riding in a threshold public goods game: experimental evidence. Journal of Economic Behavior and Organization 34, 603–620.

Coursey, D., Smith, V.L., 1984. Experimental tests of an allocation mechanism for private, public or externality goods. Scandinavian Journal of Economics 86, 468–484.

Croson, R.T.A., Marks, M., 1996. Equilibrium selection: preplay communication and learning? Working Paper, Risk Management and Decision Processes Center, Wharton School of Business, University of Pennsylvania.

Davis, D.D., Holt, C.A., 1993. Experimental Economics. Princeton University Press, Princeton, NJ.

Dawes, R., Orbell, J., Simmons, R., van de Kragt, A., 1986. Organizing groups for collective action. American Political Science Review 8, 1171–1185.

Groves, T., Ledyard, J., 1977. Optimal allocation of public goods: a solution to the ''free rider'' problem. Econometrica 45, 783–809.

Harstad, R., Marrese, M., 1982. Behavioral explanations of efficient public good allocations. Journal of Public Economics 19, 367–383.

Isaac, R.M., Schmidtz, D., Walker, J., 1989. The assurance problem in laboratory markets. Public Choice 62, 217–236.

Isaac, R.M., Walker, J., Thomas, S., 1984. Divergent evidence on free riding: an experimental examination of possible explanations. Public Choice 43, 113–149.

Isaac, R.M., Walker, J., Williams, A., 1994. Group size and the voluntary provision of public goods: experimental evidence using very large groups. Journal of Public Economics 54, 1–36.

Ledyard, J.O., 1995. Public Goods: a survey of experimental research. In: Kagel, J.H., Roth, A.E. (Eds.), Handbook of Experimental Economics. Princeton University Press, Princeton, NJ. pp. 111–194.

Marks, M.B., Croson, R., 1998. Alternative rebate rules in the provision of a threshold public good: an experimental investigation. Journal of Public Economics 67, 195–220.

Marks, M.B., Croson, R., forthcoming. The effect of incomplete information in a threshold public goods experiment. Public Choice.

Palfrey, T.R., Prisbrey, J.E., 1997. Anomalous behavior in public goods experiments: how much and why? American Economic Review 87, 829–846.

Rapoport, A., Eshed–Levy, D., 1989. Provision of step-level public goods: effects of greed and fear of being gypped. Organizational Behavior and Human Decision Processes 44, 325–344.

Rapoport, A., Suleiman, R., 1993. Incremental contribution in step-level public goods games with asymmetric players. Organizational Behavior and Human Decision Processes 55, 171–194.

Rose, S., Clark, J., Poe, G.L., Rondeau, D., Schulze, W.D., 1997. The private provision of public goods: tests of a provision point mechanism for funding green power programs. Environmental and Resource Economics Working Paper, no. 97–02. Cornell University.

Smith, V.L., 1980. Experiments with a decentralized mechanism for public goods decision. American Economic Review 70, 584–599.

Smith, V.L., 1979. An experimental comparison of three public good decision mechanisms. Scandinavian Journal of Economics 81, 198–215.

Snedecor, G.W., Cochran, W.G., 1989. Statistical Methods, 8th edn. Iowa State University Press, Ames, IA.

Suleiman, R., Rapoport, A., 1992. Provision of step-level public goods with continuous contribution. Journal of Behavioral Decision Making 5, 133–153.