Chapter 86

EXPLAINING THE COMPARATIVE STATICS IN STEP-LEVEL PUBLIC GOOD GAMES

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1. Introduction

In step-level (a.k.a. provision point) public goods a funding threshold has to be reached before the good can be provided. Large scale examples of these goods are dikes, lighthouses and bridges. Many small scale example exist at the organizational level: some initial investments in organizing the fundraising have to be made before any voluntary provision of a public good is possible (Olson, 1971, p. 22).

We consider the case where contributions exceeding the threshold do not affect the level of provision (i.e., further contributions are redundant once the threshold is reached) and where the contribution decision is reduced to a binary choice. In our set-up n group-members repeatedly face the binary decision whether or not to contribute an endowment c. If s or more of the n players contribute, a public good is provided (i.e., the contribution threshold is reached), yielding a payoff $f(s)$ to each player. Futile and redundant contributions are not refunded. In all of our experiments, we use $c = 0.60$ Dutch guilder ($\approx$ \$0.42) and $s = 3$. Hence if the contribution threshold is reached, the earnings are $f(3) - 60$ for subjects who contributed and $f(3)$ for subjects who did not. If the threshold is not reached, these earnings are 0 and 0.60, respectively.

The step-level public good game differs strategically from the linear public good game. In the one-shot linear public good game the dominant strategy is not to contribute. In the one-shot step-level public good game multiple Nash equilibria exist. An inefficient Nash equilibrium involves nobody contributing. There are efficient Nash equilibria in pure strategies where 3 of the n players contribute (i.e., there are exactly enough contributions to reach the threshold). A rational player maximizing expected value will contribute if and only if she estimates the probability that her contribution will be critical for the provision of the public good to be sufficiently high. To be more precise, she will contribute if and only if she estimates the probability that 2 of the $n - 1$ other group-members will contribute to be higher than $0.60/(f(3) - 60)$.

In various papers, we have studied different aspects of behavior in these games; for references, see Offerman (1997). In this project, we distinguish individual preferences (allowing them to be non-selfish) and individual beliefs about the behavior of others. Both beliefs and preferences are important building blocks for most theories explaining behavior in games. This note provides an overview of the results we have obtained in the project and an interpretation in terms of preferences and beliefs.

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2. Basic Experimental Tools

To enable a direct evaluation of the role of beliefs and preferences in the contribution decisions, we obtain independent measures on both in our experiments. This makes a more detailed testing of theories possible. Measures on beliefs and preferences allow us to attribute experimental treatment effects either to changes in preferences or to changes in beliefs or to both.

According to many social psychologists, different people pursue distinct goals when making decisions that affect others. A preference regarding one's own payoff relative to the payoffs of others is represented by a *value orientation*. An often used classification distinguishes the following value orientations. *Competitors* strive to be better off than others; *individualists* pursue the best for themselves and *cooperators* try to achieve outcomes that are best for both themselves and others. Social psychologists have developed a decomposed game technique that allows one to classify subjects according to their value orientation (Griesinger and Livingston, 1973; Liebrand, 1984). We measured subjects' value orientations before the start of the public good experiment, using the so-called ring test.

In every experimental period, after a subject had made the decision whether or not to contribute to the step-level public good, we measured her beliefs about how many of the other group members would contribute. Truthful and serious reporting was encouraged by using an incentive compatible quadratic scoring rule that rewards accurate expectations (Murphy and Winkler, 1970).

These experimental tools for obtaining measures on preferences and beliefs are discussed and evaluated in more detail in Offerman, Sonnemans, and Schram (1996) and Offerman (1997).

3. Treatments

We consider four changes in the institutions and environment that may affect contribution decisions.

1. We focus on *the value* $f(3)$ of the public good. Do subjects contribute more when $f(3)$ is higher, as often observed in linear public good games (Ledyard, 1995)?
2. We investigate whether individuals contribute less when *group size* n is large, as suggested by Olson (1971).
3. We address the question whether *partners* (fixed groups in a repeated game) contribute more than *strangers* (rematching in each period).
4. We test whether the *framing* of the problem matters. The problem can be posed in the usual 'positive' frame, where individuals decide whether or not to contribute and the public good is provided if and only if sufficient contributions are made. It can also be posed in a 'negative' frame, where individuals decide whether or not to withdraw their contribution and where a 'public bad' occurs (i.e., the public good is not provided) if and only if more than $n - 3$ subjects withdraw. This

Table 1
Summary of treatments

Treatment	Low7s+	High7s+	High5s+	High5p+	High5p−
f	180	245	245	245	245
n	7	7	5	5	5
Mode	Strangers	Strangers	Strangers	Partners	Partners
Frame	Public good	Public good	Public good	Public good	Public bad

Notes. The name of a treatment is mnemonic for its properties: the first part refers to the value of the public good, the number refers to group size, the subsequent letter refers to *s*trangers or *p*artners, a final + indicates that the public good frame was used, a—that the public bad frame was used. The value of the public good f is denoted in Dutch cents.

public bad game is strategically equivalent to the public good game (Sonnemans, Schram, and Offerman, 1998). Uncontrolled evidence suggests that people are more cooperative in games with a positive externality than in games with a negative externality.

Five treatments allow us to evaluate these four issues. Table 1 summarizes their features. In each treatment the game was played for 20 periods.

Figure 1 illustrates the treatment effects by showing the average contribution levels per period for each treatment. The following results are obtained.

1. The effect of a change in *the value* $f(3)$ of the public good can be evaluated by comparing treatments high7s+ and low7s+. Subjects contribute substantially and significantly more when the value of the public good is high than when it is low. The difference between the treatments increases over time, because there is an end-period effect in low7s+ but not in high7s+.
2. Increasing *group size* n while keeping all other parameters constant decreases the average contribution level per individual: subjects contribute consistently and significantly more in high5s+ than in high7s+. Nevertheless, the public good is provided more often when groups are large, because it is easier to reach the threshold with more people (cf. Table 2).
3. Whether subjects play in the *partners* mode or in the *strangers* mode does not systematically affect behavior in our experiments: the difference between high5s+ and high5p+ is negligible and not significant.
4. The *framing* of the problem matters: subjects contribute significantly more in the public good frame (high5p+) than in the public bad frame (high5p−). The difference is negligible in early periods but increases substantially.[1]

[1] For a linear public good game, Andreoni (1995) also finds that subjects contribute more in a positive frame than in a negative one. In his experiments, the difference is more or less stable across periods.

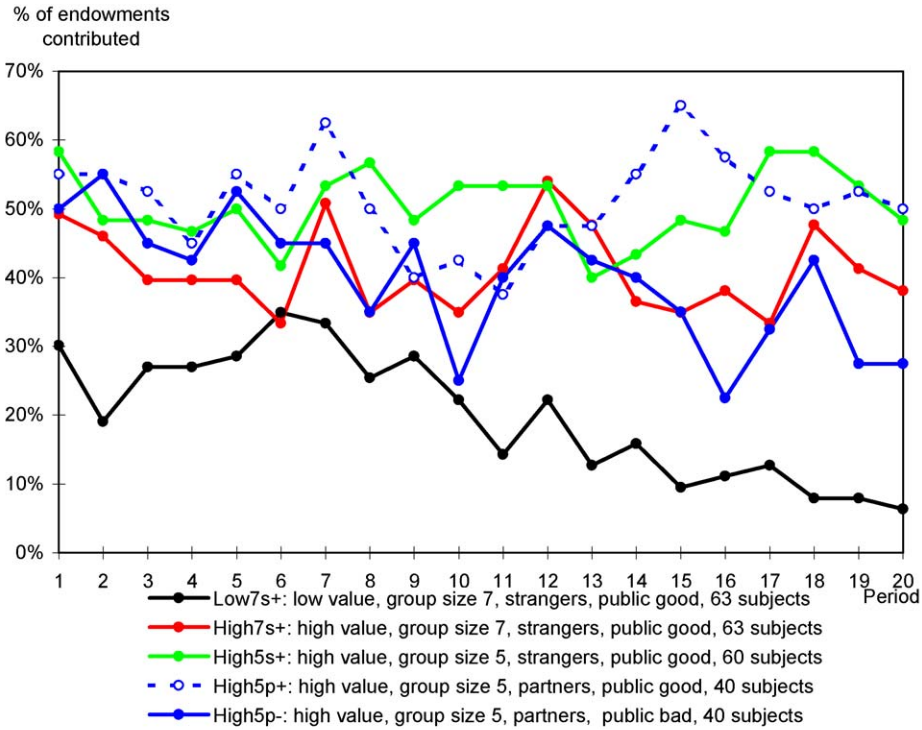

Figure 1. Percentage of contributions per period.

Table 2
Mean contribution per treatment

Subjects	Individualists	Cooperators	All	% periods in which the threshold is reached
Low7s+	16.5% ($n = 49$)	28.5% ($n = 10$)	19.8% ($n = 63$)	18.3%
High7s+	38.7% ($n = 38$)	48.1% ($n = 21$)	41.0% ($n = 63$)	61.7%
High5s+	46.2% ($n = 34$)	60.0% ($n = 19$)	50.4% ($n = 60$)	51.3%
High5p+	43.3% ($n = 18$)	54.1% ($n = 17$)	51.1% ($n = 40$)	50.6%
High5p−	33.9% ($n = 23$)	50.0% ($n = 12$)	39.9% ($n = 40$)	31.3%

Note. The number of individuals is given in parentheses. Low7s+: low value, group size 7, strangers, public good; High7s+: high value, group size 7, strangers, public good; High5s+: high value, group size 5, strangers, public good; High5p+: high value, group size 5, partners, public good; High5p−: high value, group size 5, partners, public bad.

4. Interpreting the Results

How can these treatment effects be explained? A first possibility is that they are an artifact caused by subject types (which we measured through their value orientation). It may be that cooperators contribute more than individualists and that treatment effects are due to different mixtures of these types in different sessions.[2] In fact, in all treatments subjects that are classified as cooperators on the basis of the ring test contribute consistently and significantly more than subjects classified as individualists. Nevertheless, differences between cooperators and individualists cannot account for any of the treatment effects, because the effects carry over to both types of subjects. For example, both cooperators and individualists contribute more when the value of the public good is high than when it is low. Table 2 gives the mean contributions (across 20 periods) per treatment for these two types.

The treatment effects we observed in Figure 1 may be due either to differences in preferences or to differences in beliefs. Subjects may contribute more in a particular treatment because they attribute higher utility to contributing (or more utility to achieving the public good) or because they estimate the probability of being critical higher than in other treatments. Figure 2 focuses on these explanations: it presents logit regression results per treatment.[3] The choice whether or not to contribute is explained by the estimated probability of being critical. In addition, Figure 2 presents the average estimated probabilities of being critical per treatment.

Note that in all treatments a clear positive relationship exists between the estimated probability of being critical and the inclination to contribute. Rational choice theory predicts a step function. If utility is given by expected value, the probability of contributing should go from 0 to 1 when the probability of being critical is estimated to be 0.324 (0.5 for low7s+).[4]

The logit results and the average probabilities presented in Figure 2 allow us to analyze whether observed treatment effects are due to differences in beliefs or in preferences (in the latter case, different contribution decisions are made for the same belief). We do so for the various effects we observed.

1. For any estimated probability of being critical, subjects are more likely to contribute to the public good in high7s+ than in low7s+, while their estimates of being critical are more or less the same on average. Hence, the effect that subjects contribute more when the *value* is high is not a consequence of differences in beliefs but can be attributed to differences in preferences.

[2] Overall 61% of our subjects were classified as individualists and 30% as cooperators. The remaining subjects were classified as competitors or could not be classified because their consistency in the ring test was too low.

[3] The exact estimates of the logit equations are presented in Offerman (1997).

[4] Our data show an unexpected result w.r.t. the estimated probabilities of being redundant (the case where the good is provided irrespective of an individual's contribution). Like Caporael et al. (1989), we find that contributions increase with a rise in this probability.

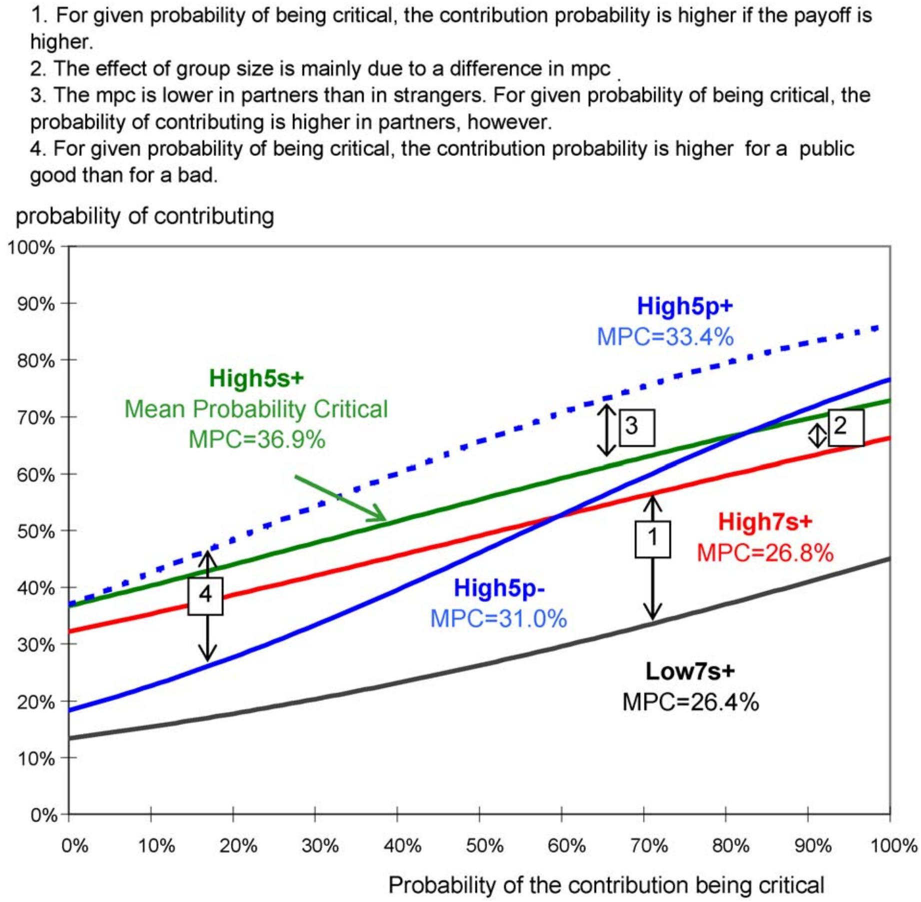

Figure 2. Logit regressions.

2. We observed a decrease in contributions with an increase in *group size*. Figure 2 shows that the estimated probability of being critical is much higher in high5s+ than in high7s+. For any given probability of being critical, subjects are only slightly more likely to contribute in small groups than in large groups, however. We conclude that this effect is better explained by a difference in beliefs than by a difference in preferences.
3. We did not observe an effect of *partners* versus *strangers*. Figure 2 shows that the estimated probability of being critical is lower in the partners condition (high5p+) than in the strangers condition (high5s+). On the other hand, given a probability of being critical, partners are more likely to contribute. These two effects are small and compensate each other.

4. Finally, the difference in contribution level between the *public good* frame and the *public bad* frame seems to be largely due to a difference in preferences. The difference in average beliefs is small and the logit function of high5p+ lies well above that of high5p−.

These experimental results show that both preferences and beliefs play an important role in determining behavior in step-level public good games. Elsewhere, we have studied in more detail how value orientations might affect decision rules and how the interaction between players may affect beliefs in a way consistent with our findings. The following summarizes the results obtained.

For preferences, we consider the subjects with a cooperative value orientation. Their 'other regarding' preferences can be modeled by specific mappings from payoff to utility. We distinguish the following three. First, *material cooperators* attach extra utility to the provision of the public good. Second, *warm-glow cooperators* acquire extra utility from the act of contributing (Andreoni, 1990).[5] Third, *in-group cooperators* obtain additional utility if the good is provided, but only if they contributed. Maximum likelihood results, allowing for differences between individualists and cooperators, favor the warm glow interpretation (Offerman, 1997, pp. 100–103). Moreover, the warm-glow interpretation can explain the result that subjects' preferences in high7s+ and high5s+ are more or less equal, which is hard to rationalize with the material cooperators interpretation (if individuals care for the material welfare of others, they should be more inclined to contribute when the public good accrues to more individuals).

When analyzing the interaction between players, one may follow either a learning (disequilibrium) route or a rational (equilibrium) route. Belief learning models are in the former group of studies. They assume that players update a prior belief about the behavior of others on the basis of observed behavior. In these models, players assume that the distribution of others' behavior is constant in some probabilistic sense. Given their beliefs, they myopically maximize expected utility. On the other hand, equilibrium models assume that players have rational expectations, i.e., their beliefs are consistent with the actual play of the others. One could judge theories on their ability to predict comparative statics, like the ones described above. Unfortunately, the treatment effects can be rationalized by both learning and equilibrium models and can therefore not be used to discriminate between them. (For a discussion, see Offerman, 1997, chapter 2.) Nevertheless, Offerman, Schram, and Sonnemans (1998) compare a quantal response naive Bayesian model (where players update beliefs naively and give noisy best responses) with a quantal response equilibrium model (where players have rational expectations and give noisy best responses). Maximum likelihood results reveal that the naive Bayesian model describes actual choices better than the equilibrium model. Moreover, an analysis of reported beliefs makes clear that there is a systematic updating

[5] For linear public goods games Anderson, Goeree, and Holt (1998) show theoretically that evidence of group size effects can be rationalized by allowing for (linear) altruism. This corresponds to our material cooperators. On the other hand, Palfrey and Prisbrey (1998) find no evidence of linear altruism but do find warm glow.

pattern in subjects' beliefs, a pattern that is consistent with belief learning models but not with existing game theoretic models (Offerman, 1997, pp. 132–139).

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