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AN EXPERIMENTAL ANALYSIS OF CONDITIONAL COOPERATION*

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WP-AD 2006-24

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Editor: Instituto Valenciano de Investigaciones Económicas, S.A.
Primera Edición Noviembre 2006
Depósito Legal: V-4862-2006

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* Fatas acknowledges financial support from the Spanish Ministry of Science and Education (SEJ2004 07554/ECON) and the Ivie.

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ABSTRACT

Experimental and empirical evidence identifies the existence of social preferences and proposes competing models of such preferences. In this paper, we further examine one such social preference: conditional cooperation. We run three experimental public goods games, the traditional voluntary contribution mechanism (VCM, also called the linear public goods game), the weak-link mechanism (WLM) and the best-shot mechanism (BSM). We then analyze the existence and types of conditional cooperation observed. We find that participants are responsive to the past contributions of others in all three games, but are most responsive to *different* contributions in each game: the median in the VCM, the minimum in the WLM and the maximum in the BSM. We conclude by discussing implications of these differences for behavior in these three mechanisms. This paper thus refines our notions of conditional cooperation to allow for different types of public good production functions and by extension, other contexts.

Keywords: experimental economics, conditional cooperation, public goods, voluntary contribution mechanism, weakest link mechanism, best-shot mechanism.

JEL Classifications: C72, C92, D44, H41

I. INTRODUCTION

A recent spate of theories has emerged to formalize pro-social preferences as observed in experiments and in real life (see Sobel, 2005 for an outstanding review). This paper focuses on one category of these preferences—conditional cooperation, also called reciprocal or matching preferences (e.g. Sugden 1984). Here, individuals prefer to cooperate with or help those who have helped them in the past, but not those who have acted selfishly.

These conditional preferences have been observed in many lab experiments, as well as in the field. In the lab, Fehr and Fischbacher (2002) and Camerer and Fehr (2006) review evidence on conditional cooperation and reciprocal behavior and discuss their impact on core issues in economics. Individual papers identifying conditional cooperation in linear public goods games include Croson (1998), Keser and van Winden (2000), Brandts and Schram (2001), Fishbacher et al (2001), and van Dijk et al. (2002). More recently, Andreoni and Petrie (2004), Croson et al. (2005), and Andreoni and Samuelson (2006) provide both evidence in favor of conditional cooperation and some nice examples of the importance of a deeper understanding of the mechanisms underlying these motivations.

Many field experiments also show the existence and impact of conditionally cooperative behavior in natural settings. Falk (2004) and Frey and Meier (2004a and 2004b) use large-scale field experiments involving the decisions of thousand of individuals (from 10.000 to 33.000). These papers find strong evidence in favor of reciprocal or conditionally cooperative behavior. List (2004) and Shang and Croson (2006) show the impact of conditional cooperation in smaller-scale field experiments on the voluntary provision of public goods.

In this paper we present experimental results from three public goods environments testing the existence *and forms* of conditionally cooperative preferences. We begin with the well-known voluntary contribution mechanism (VCM, also known as the linear public goods game), where conditionally cooperative preferences have primarily been explored. Next we move to two relatively under-studied games, the weakest link mechanism (WLM) and the simultaneous best-shot mechanism (BSM). Behavior in these games is of interest in and of themselves, in that the games are often used to model public goods provision, as well as team production in firms and other social dilemma-type problems. Further, we are the first to identify the existence of conditional cooperation preferences in the WLM and the BSM. But the main contribution of our paper lies in the comparison between the *forms* of conditional cooperation in these three contexts. In particular we ask: to what previous action do individuals most strongly respond in these games?

These games differ in fundamental ways, both economically and psychologically. In the VCM, the amount of public good produced depends on the *total or average* of individual contributions. Thus one might imagine that the average or median contribution of others is psychologically most salient in determining one's own contribution. In the WLM, the amount of public good produced depends on the *minimum* of all contributions. Thus one might imagine that the minimum contribution of others is psychologically most salient in determining one's own contribution. In the BSM, the amount of public good produced depends on the *maximum* individual contribution. Thus one might imagine that the maximum contribution of others is psychologically most salient in determining one's own contribution.

In this paper we examine the decision-making processes in all three institutions. First, we will describe behavior in each game, finding deviations from equilibrium predictions in all treatments along with some convergence to equilibria over time. Second, we will examine the impact of counterparts' previous contributions on one's own contribution in each treatment. We find, as predicted, that the most salient focus in the VCM is the median contribution of others, in the WLM is the minimum contribution of others and in the BSM is the maximum contribution of others. Finally, we present an analysis that compares between games, and shows that individuals respond more to the median in the VCM than the other two games, more to the minimum in the WLM than the other two games, and more to the maximum in the BSM than the other two games.[1] We conclude with a discussion of the importance of understanding not just the existence of conditional cooperation, but its specific form in making predictions and explaining economic behavior.

The rest of the paper is organized as follows: Section 2 discusses the games, previous research that has been conducted in each, and their experimental implementation. Section 3 reports the experimental results and Section 4 concludes.

[1]Croson et al. (2005) present some early results on conditional cooperation using a subset this data as well. In that paper, we examine only the VCM and the WLM games. In addition, we show only that in the VCM contributions react to the median contribution of others (with no comparisons to the minimum or maximum) and in the WLM contributions reach to the minimum contribution of others (with no comparisons to the median or maximum). In addition, this paper provides a comparison between the VCM, WLM and BSM which has not been previously documented.

II. THE EXPERIMENTAL ENVIRONMENT

II.1. *The voluntary contribution mechanism (VCM)*

In economic experiments, the most common public goods institution is the VCM (see Ledyard, 1995 or Keser, 2002 for a review). In this mechanism, the amount of public good produced is determined by the total (or average) contribution of others in the group, as described below. The game has a unique equilibrium of full free-riding (dominant strategy in the one-shot game, unique Nash in the finitely repeated game). Previous research has documented that individuals contribute significantly more than the predicted level of zero, although there is much speculation about exactly why. Previous research has identified conditional cooperation in this area.

Our experimental environment mirrors those of previous experiments. N=4 subjects are endowed with e_i*=50 Cents* and are asked to simultaneously and privately allocate this endowment between a public and a private account. The payoff of each individual i is determined by the sum of his allocation to the private account and twice of the group´s average allocation to the public account.[2] If e = average (e_1, e_2, e_3, e_4), i´s payoff is given in equation (1).

$$\pi_i = (50 - e_i) + 2e \qquad (1)$$

II.2. *The weakest link mechanism (WLM)*

The WLM was introduced by Hirschelifer (1983). In this mechanism, the amount of public good produced is determined not by the average (or total) contribution as in the VCM, but by the minimum contribution of the group. This mechanism has been used to capture features of joint production (van Huyck et al. 1990, Reichman and Weimann 2004), meeting start-times and submitting chapters for books (Weber, Camerer and Knez 2004), or coordination failure in organizations (Brandts and Cooper 2006) **.**

A few experimental studies have been published using the WLM. Van Huyck, Battalio and Beil (1990) designed similar (minimum effort) coordination games with seven symmetric Pareto-ranked equilibria that were played by large groups repeatedly in the laboratory. They

[2]Note that the notation of the team production function in equation (1) is non-standard; usually the return from the team production is formally presented by the sum of contributions and a marginal per capita return of ½ = 2/N, where N=4 is the number of team members. We choose this presentation to highlight the parallelism between this game and the other games.

conclude that the selection of the payoff-dominant equilibrium is extremely unlikely as all their experiments converge quickly to the most inefficient equilibrium.

Other authors have searched for strategies to improve coordination on pareto-superior equilibria. Strategies explored include reducing the number of players (Van Huyck et al. 1990), adding money back guarantees and thus decreasing the costs of contributing (Fatas et al. 2006), adding entry fees in order to play the game (Cachon and Camerer 1996), using sequential rather than simultaneous play (Weber et al. 2004), increasing the number of repetitions (Berninghaus and Erhard 1998), adding pre-play communication (Riechmann and Weimann 2004, Broseta et al. 2003), adding between group competition (Bornstein et al. 2002 and Riechmann and Weimann 2004) and excluding low-contributing players (Croson et al. 2006). However, as far as we know, none of the previous studies has focused on the role of conditional cooperation in this setting; that is, to which information do individuals react making their own decisions?

Our experimental parameters for the WLM were chosen to make it as similar to the classical VCM as possible. Four team members simultaneously and privately make decisions of how much e_i*=50 Cents* to allocate to the private and public account. Public good is produced according to a Leontief production technology from this account; thus the minimum contribution determines the output, all contributions in excess of the minimum are lost. If $\underline{e}$ = min $\{e_1, e_2, e_3, e_4\}$ is the smallest order statistic of contribution, *i*'s payoff is given in equation (2).

$$\pi_i = (50 - e_i) + 2\underline{e} \tag{2}$$

Each symmetric strategy profile, i.e., each allocation in which every subject contributes the same amount constitutes a Nash equilibrium. The payoffs in these equilibria are the same to all subjects and increase linearly in the minimum effort, $\pi_i = 50 + \underline{e}$. Hence, the equilibria are Pareto-ranked, with the payoff-dominant equilibrium being maximum contribution but the risk-dominant equilibrium being zero contribution.

II.3. *The best shot mechanism (BSM)*

The best shot mechanism was also introduced and analyzed by Hirshleifer (1983). Here the amount of public good provided depends on the maximum contribution of the group. This game has been used to analyze production technologies like R&D or other discoveries, where groups may be working simultaneously, but only the contributions of the one that "wins" create value.

The equilibria of this game are complicated. In particular, there are N asymmetric but efficient equilibria of the stage game, where N is the number of players in the game (for us, N=4). In each of these equilibria, one player fully contributes to the public good, while the other players fully free-ride, contributing nothing. The problem then becomes, which equilibria will be coordinated on by the group, especially since the equilibrium payoffs are unequal: the free-riding players earn significantly more than the full-contributor. Thus this game yields an impure coordination problem, sometimes called the "volunteers dilemma," where one player must volunteer to be the full contributor. In the finitely repeated game, of course, any sequence of these stage-game equilibria is itself an equilibrium.[3]

The best shot mechanism has been experimentally explored in an easier-to-solve sequential version with two players by Harrison and Hirshleifer (1989), Prasnikar and Roth (1992), Duffy and Feltovich (1999), Andreoni et al. (2002), and Carpenter (2002). Here, however, we run a simultaneous version of the game where four participants decide how much of their endowment to allocate to the public account at the same time as other subjects in their group are making the same decision. If $\bar{e}$ = max $\{e_1, e_2, e_3, e_4\}$, then individual *i*'s payoff is.

$$\pi_i = (50 - e_i) + 2\bar{e} \tag{3}$$

Of primary interest, however, is not simply behavior in these games, although we will report behavior and its relationship with equilibrium predictions briefly. Instead, we are interested in the existence and form of conditional cooperation. We expect that players in these games will react to the previous actions of their counterparts. But we expect that *which* action is salient will depend on the game. In particular, we predict that players will react to the average (mean or median) contributions of others in the VCM, the minimum contribution of others in the WLM and the maximum contribution of others in the BSM.

[3]Additionally, there exists a mixed strategy equilibrium in which each subject contributes their endowment to team production with a probability of $(1-p^{N-1})$, where p=½ for our parameters (see Croson et al. 2006). Several other (less efficient) mixed strategy equilibria exist as well.

II.4. *The experimental procedure*

In this paper we report the results of computerized experiments, which closely replicate environment, information and payoff structures of previous literature.[4] The experiments involved 24 economics undergraduates in each of the first two treatments (VCM and WLM) and 48 in the third one (the BSM). We use a between-subject design, thus each subject participates in only one treatment. Subjects were randomly allocated into groups of four as they arrived into the lab. None of the subjects had previously participated in a public goods experiment.

The experiments entailed a ten period finitely repeated game. We used a partners procedure, so participants´ randomly-formed groups of four remained together throughout the game. Instructions were written in neutral language, referring to allocations of cents rather than contributions. Before the experiment, participants completed a quiz to ensure that they understood the payoffs involved in the experiment, and there was an informal post-experimental survey to elicit participants' thoughts about the experience. Instructions, quizzes and surveys, and a summary of their results, are available from the authors.

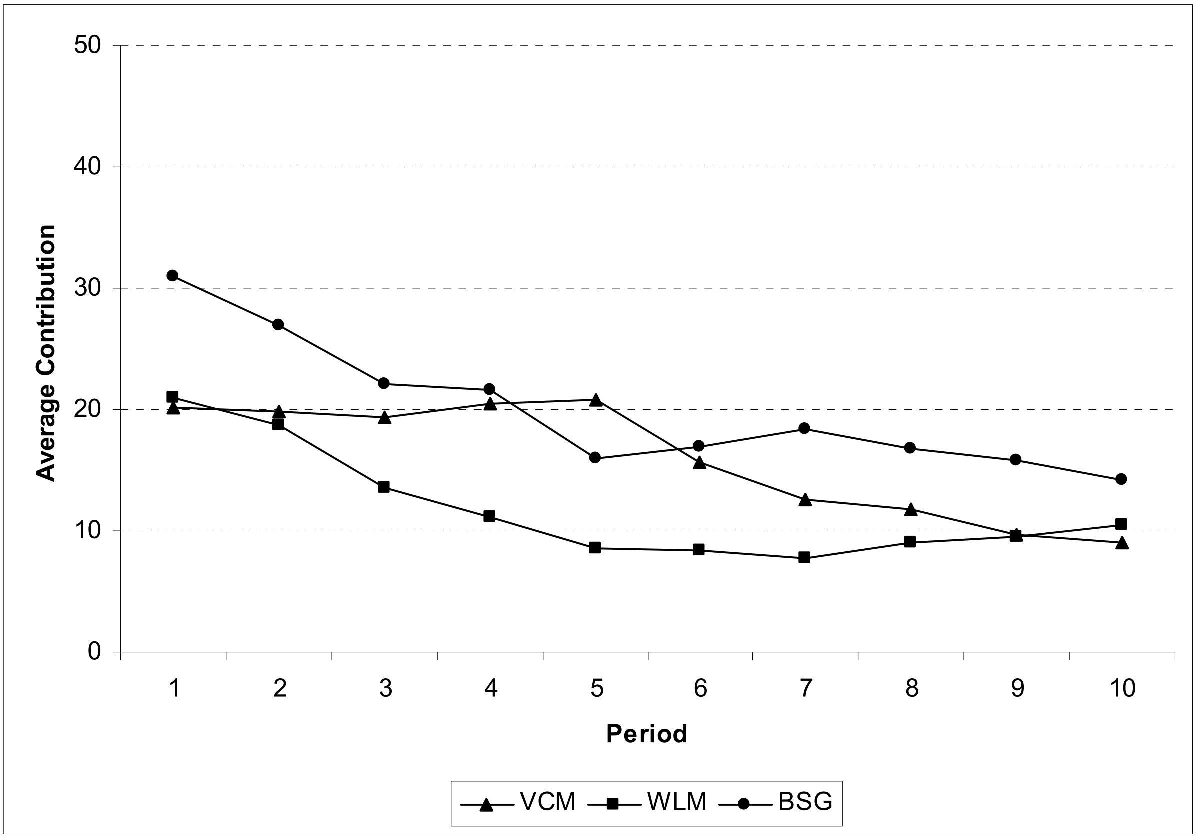
After each round of the game, participants were told the individual contributions of the other three members of their group in increasing order of contribution; individual contributions were not identified with their contributor such that it was impossible to trace individual contributions (as in Croson 2000). Additionally, subjects were informed about their own earnings both in total and subdivided by private and public accounts. Average earnings of a subject were €10.43 in the WLM experiments, €13.06 in the VCM and €16.22 in the BSM. Experiments took less than an hour to run.

III. EXPERIMENTAL RESULTS

Figure 1 shows the average contributions to the public good in each of the three environments over the 10 rounds.

[4]Urs Fischbacher's z-tree was used for the computer programme.

Figure 1: Average Allocations to the Public Good



III.1 *Consistency with previous results*

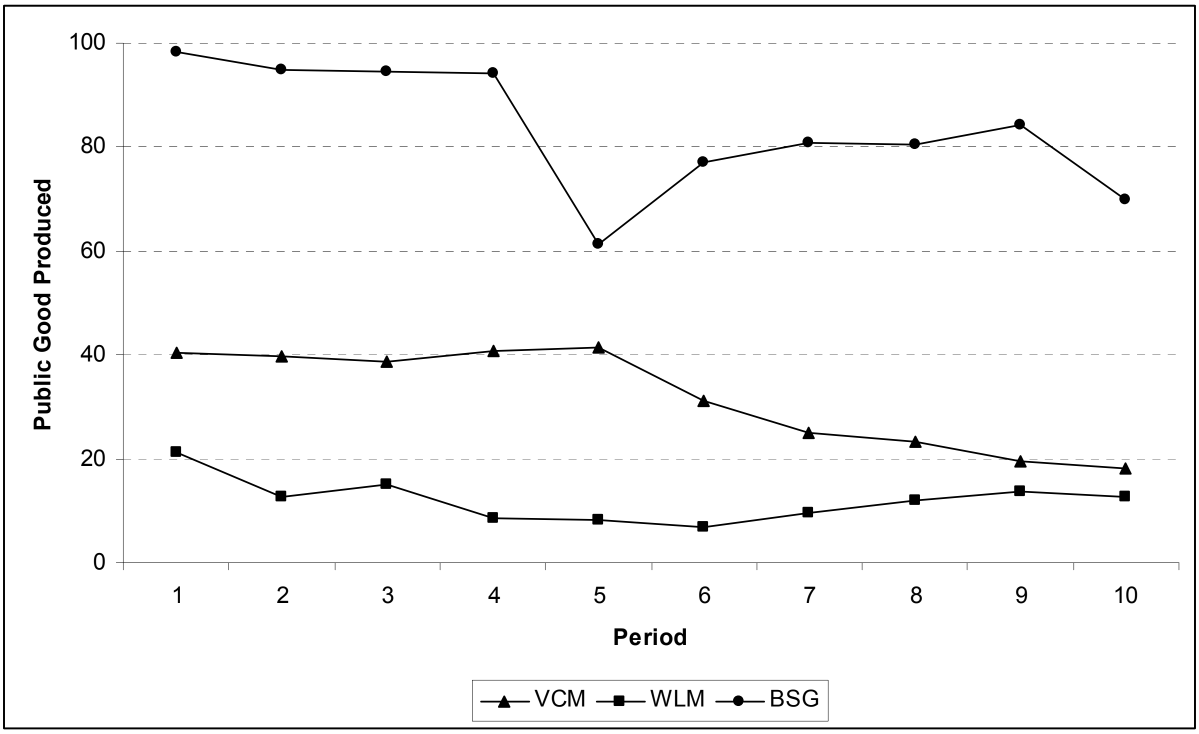
Replicating previous studies, we find behavior that is significantly different than that predicted by equilibrium analysis. Allocations to the public good in the VCM are significantly different than zero, starting at around 40% of endowment and then declining over the length of the game. Allocations in the WLM are also not at equilibrium; in only 2 out of the 60 periods (10 periods for each group times six groups), the individuals in the groups allocated the same amounts to the public good. Allocations in the BSM also deviate from equilibrium. In only 9 out of 120 periods does one player contribute his entire endowment while the others contribute zero.

We also observe contributions decreasing over the game, consistent with previous experiments. A GLS regression of contributions on period number and including an indicator variable for each subject and each group produces a significantly negative coefficient on period for all three games (VCM β=-1.44, p<.0001; WLM β=-1.16, p<.0001; BSM β=-1.59, p<.0001).[5]

III.2 *Public Good Production and Efficiency*

Figure 2 shows the amount of public good produced in each of the three environments. The total possible is 100 in each of the three games.

Figure 2: Amount of Public Good Produced

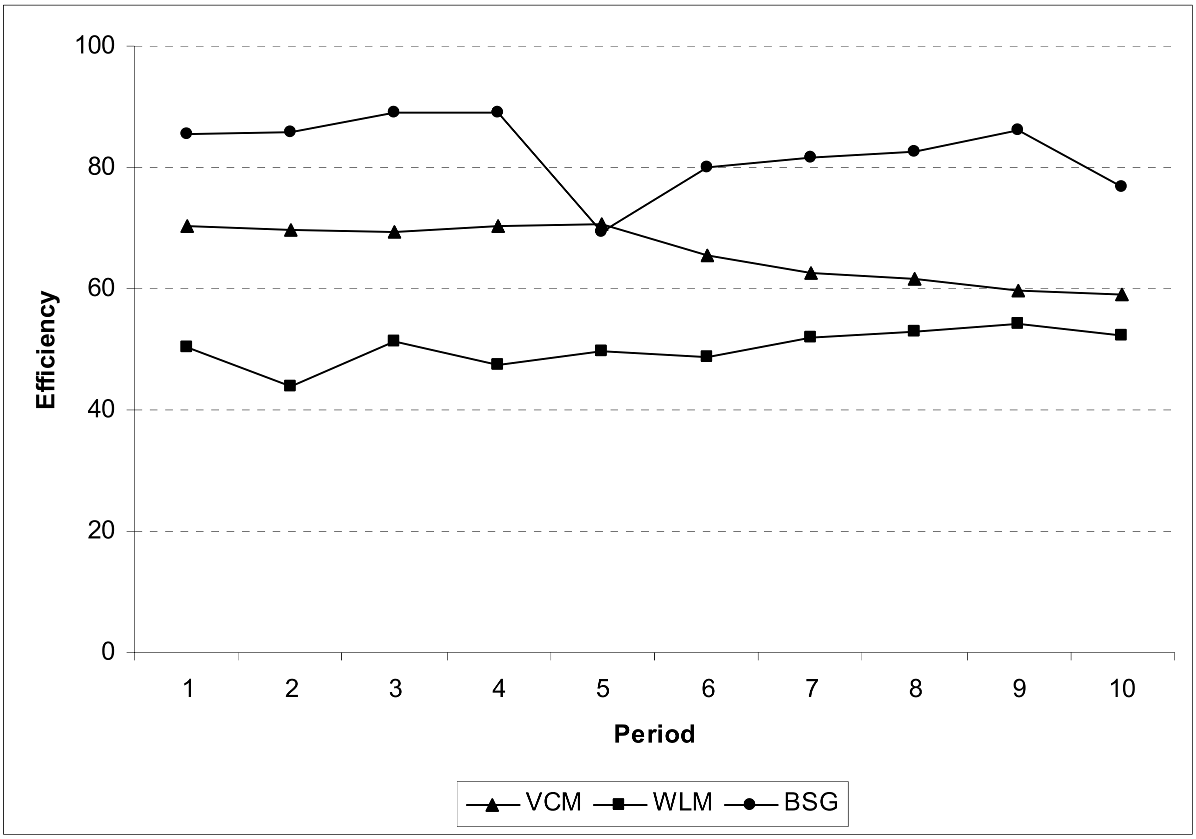


The amount of public good produced is much higher in the BSM than in the other two mechanisms, with the VCM yielding a middle level and the WSM the lowest level.

However, more public good does not necessarily imply more efficiency in the WLM or the BSM (although it does in the VCM). For example a contribution distribution like {50, 50, 50, 50} will generate 100 units of public good in the BSM, yet is quite inefficient compared with the equilibrium contribution of {50, 0, 0, 0}. Figure 3 graphs the efficiency levels observed in the three games by comparing the earnings of each group with the total possible earnings they could have had in the most efficient outcome (not necessarily an equilibrium outcome).

[5]Complete regressions data available upon request.

Figure 3: Efficiency: Percentage of Possible Group Earnings Captured



We find the highest efficiency levels in the BSM, with the VCM again in the middle and the WLM at the bottom.

III.3 *Conditional cooperation*

But the focus of our paper is on identifying the decision rules in these environments. A number of competing models have been proposed to explain deviations both from equilibrium and from efficiency, like those found above. One set of those models involve reciprocity (also called matching, also called conditional cooperation).[6] In these models, participants react to the allocations of their counterparts (either previous or current). Thus if others contribute to the public good you want to contribute, while if others free-ride you want to keep your endowment for your private consumption.

[6]See, e.g., Sugden (1984), Rabin (1993), Charness and Rabin (2002), Dufwenberg and Kirchsteiger (2004), Segal and Sobel (2006) and Falk and Fischbacher (2006), along with Sobel´s (2005) review.

We follow Croson (1998) in analyzing allocations to test this explanation. We begin with running one regression for each game. The dependent measure is individual i's contribution to the public good in period t. Independent variables include indicator variables for the period t, for each individual, for each group and, of most interest, a measure of what the individual's counterparts did last period

In each of the three games, we compare the significance of all three lagged individual decisions: LagMax, LagMed and LagMin. LagMax indicates the maximum contribution to the public good observed by a subject in the previous period, not including their own, LagMed the intermediate contribution and LagMin the minimum. As the group size is four, there are only three relevant decisions (the contribution of the subject himself is excluded).

Note that in the different games, each of the contributions has a different meaning from the efficiency point of view. For example, in the WLM, the LagMin contribution determined the amount of public good provided in the previous period, while it had no impact on earnings in the BSM and only contributes to earnings in the VCM. This observation forms the basis of our hypothesis that participants will respond to LagMin in the WLM, and LagMax in the BSM.

The regressions are run using random effects regression[7] and the equation is:

$$cont_{it} = \beta_0 + \beta_1\, LagMax_{-it-1} + \beta_2\, LagMed_{-it-1} + \beta_3\, LagMin_{-it-1} + \sum_{t=2}^{10} \tau_t t + \sum_{g=2}^{G} \gamma_g g + \sum_{i=(N-g)}^{N} \alpha_i i + \varepsilon_{igt}$$

where $cont_{it}$ is i´s contribution in period t, $LagMax_{-it-1}$ denotes the lagged maximum contribution of i's partners in the previous period, $LagMed_{-it-1}$ denotes the lagged intermediate contribution of i's partners in the previous period and $LagMin_{-it-1}$ denotes the lagged minimum contribution of i's partners. We include an indicator variable for each period except the first, an indicator variable for each group G except the first, and an indicator variable for each individual, excluding one per group to avoid colinearity. The error term is estimated with random effects for period, group and individual.

In addition, we run a parallel regression for each game using standardized regression (standardizing the independent variables of interest). This allows us to compare the size of the resulting coefficients directly, in addition to comparing their statistical significance. The results are presented for each game separately, in Table 1 to 3.

[7]This approach has been used, for instance, in Croson (1998). For further reading see Greene (2000).

Table 1: Conditional Cooperation in the VCM

	Estimate (SE)	P		Estimate (SE)	P
Intercept	8.06 (2.04)	<.0001		14.99 (0.59)	<.0001
LagMed	0.26 (0.13)	.0586			
LagMin	0.23 (0.12)	.0652			
LagMax	0.05 (0.09)	.5865			
LagMedSTD				2.71 (1.42)	.0586
LagMinSTD				2.05 (1.11)	.0652
LagMaxSTD				0.60 (1.10)	.5865
Period	Yes			Yes	
Subject	Yes			Yes	
Group	Yes			Yes	
N	216			216	
R^2 Adjusted	0.6071			0.6071	

Table 2: Conditional Cooperation in the WLM

	Estimate (SE)	P		Estimate (SE)	P
Intercept	5.87 (1.23)	<.0001		11.06 (0.47)	<.0001
LagMed	0.02 (0.12)	.8639			
LagMin	0.65 (0.15)	<.0001			
LagMax	0.01 (0.07)	.8610			
LagMedSTD				0.15 (0.90)	.8639
LagMinSTD				3.66 (0.87)	<.0001
LagMaxSTD				0.13 (0.76)	.8610
Period	Yes			Yes	
Subject	Yes			Yes	
Group	Yes			Yes	
N	216			216	
R^2 Adjusted	0.4595			0.4595	

Table 3: Conditional Cooperation in the BSM

	Estimate (SE)	P		Estimate (SE)	P
Intercept	23.62 (2.28)	<.0001		19.01 (0.80)	<.0001
LagMed	-0.09 (0.07)	.1873			
LagMin	0.16 (0.09)	.0807			
LagMax	-0.11 (0.06)	.0548			
LagMedSTD				-1.53 (1.16)	.1873
LagMinSTD				1.61 (0.92)	.0807
LagMaxSTD				-2.07 (1.08)	.0548
Period	Yes			Yes	
Subject	Yes			Yes	
Group	Yes			Yes	
N	432			432	
R^2 Adjusted	0.4343			0.4343	

Croson (1998) and Croson et al. (2005) showed that the average or median contribution is salient to the participants in a VCM game, and positively related to their own allocations. As can be seen in Table 1, the lagged median contribution is the closest to statistical significance in the VCM (p=.0586), with the lagged minimum contribution also being marginally significant (p=.0652). In the standardized regression, the coefficient on the lagged median is larger than that on the lagged minimum (2.71 versus 2.06), suggesting that individuals react more to the lagged median than the other three measures, consistent with previous research.

In the WLM (Table 2), as predicted only the lagged minimum contribution is statistically significant (p<.0001); the coefficients on the other two variables of interest are both nonsignificant. Similarly, in the standardized regression, the coefficient on lagged minimum is much larger than the other two (3.66 versus 0.15 and 0.13), confirming our hypothesis that in the WLM individuals move their contributions in response to the minimum contribution of the rest of the group, rather than the median or maximum.

Finally, Table 3 examines the BSM. Here, the lagged maximum contribution comes closest to statistical significance (p=.054). Interestingly, the coefficient on this parameter is negative, suggesting that as the lagged maximum contribution of others increases, one´s own contribution *decreases*. While this is not the typical conditional cooperation pattern, it is entirely consistent with the payoffs and resulting efficiency properties of the BSM. Remember that in this game any contributions other than the maximum are lost, and thus represent a decrease in total social efficiency. Thus if someone else is contributing more, there is no benefit either to oneself or to the group of contributing more. Thus the negative relationship between the lagged maximum contribution and one´s own contribution makes perfect sense. Similarly in the standardized regression, the coefficient on the lagged maximum variable (-2.06) is larger (in absolute terms) than the other coefficients (1.61, -1.53). This again reinforces our hypothesis that it is the most powerful factor impacting current contributions in this game.

The previous analysis looked within each game, but what about comparisons between the three games? Table 4 provides exactly this. For this analysis, we again use the individual contribution as the dependent variable, and include indicator variables for period number (2-10), subject, and group. Since we are using data from all three games, we also include indicator variables for the game type. Our main independent variables of interest are the lagged median (LagMed) *interacted with* a dummy for the VCM game (VCM), the lagged minimum (LagMin) interacted with a dummy for the WLM game and the lagged maximum (LagMax), interacted with a dummy for the BSM game. If these interactions are significant, this tells us that the effect of these lagged variables is different in the different games as indicated above. The regression equation is thus:

$$cont_{it} = \beta_0 + \beta_1 LagMax_{-it-1} * BSM + \beta_2 LagMed_{-it-1} * VCM + \beta_3 LagMin_{-it-1} * WLM + \sum_{t=2}^{10} \tau_t t + \sum_{T=VCM,WLM} \kappa_T T + \sum_{g=4}^{G} \gamma_g g + \sum_{i=(N-g)}^{N} \alpha_i i + \varepsilon_{igt}$$

As above, we present a second regression using standardized measures, so that coefficients can be directly compared. Results are presented in Table 4.

The interaction variables are all significant or marginally significant. As predicted, players respond (marginally) more to the lagged median in the VCM than in the other two games (p=.0952), significantly more to the lagged minimum in the WLM than in the other two games (p=.0032) and significant more (negatively) to the lagged maximum in the BSM than in the other two games (p=.0006). From the standardized regression, consistent with these results, the effects are the largest for the BSM (-2.16), next for the WLM (1.51) and smallest for the VCM (0.98).

Thus the results from our experiment broadly support our hypotheses. We replicate the finding that individuals are conditional cooperative in these settings with strategic interactions. However, looking within the three games we find different *types* of conditional cooperation. Participants´ contributions are responsive to the median contribution of others in the VCM, as has been previously found. But contributions are responsive to the *minimum* contribution of others in the WLM, and (negatively) to the *maximum* contribution in the BSM. Furthermore, conditionally cooperative behavior is significantly different in the three games, with the focal contribution (median in VCM, minimum in WLM and maximum in BSM) having more explanatory power in its companion game than in the other two.

Table 4: Conditional Cooperation Comparing the Games

	Estimate (SE)	P		Estimate (SE)	P
Intercept	14.64 (0.51)	<.0001		16.89 (0.57)	<.0001
LagMed*VCM	0.07 (0.04)	.0952			
LagMin*WLM	0.16 (0.06)	.0032			
LagMax*BSM	-0.12 (0.04)	.0006			
LagMedSTD*VCM				0.98 (0.58)	.0952
LagMinSTD*WLM				1.51 (0.51)	.0032
LagMaxSTD*BSM				-2.16 (0.62)	.0006
Period	Yes			Yes	
Subject	Yes			Yes	
Group	Yes			Yes	
Treatment	Yes			Yes	
N	864			864	
R^2 Adjusted	0.4737			0.4737	

IV. DISCUSSION AND CONCLUSIONS

This paper examines not just the existence but also the form of conditionally cooperative behavior in three different public goods games, the standard voluntary contribution mechanism (VCM) or linear public goods game, where it has been previously studied, and two public goods games where conditional cooperation had not been previously documented: the weakest link mechanism (WLM) and the best shot mechanism (BSM). We hypothesize and show that individuals exhibit conditional cooperation in all three settings, but that it takes a different form in each.

In the VCM we replicate previous results, showing that individuals react to the median (or average) contribution of others. In the WLM, we show that individuals react to the minimum contribution of others, which makes sense since it is this minimum that determines the amount of public good produced and resulting efficiency. Finally, in the BSM we show that individuals react *negatively* to the maximum contribution of others. Again, this makes sense, since as one participant increases their contribution, increased contributions from other group members are simply wasted, and thus both efficiency and self-interest are enhanced when those contributions decrease. In addition to showing the existence of this focal contribution within each game, we present an analysis comparing the three games. We find that individual contributions vary (marginally) more with the median contribution in the VCM than in the other two games, significantly more with the minimum contribution in the WLM than in the other two games, and significantly more (negatively) with the maximum contribution in the BSM than in the other two games.

We believe that this paper makes a number of contributions. First, it presents the first experiment on the simultaneous BSM, which had been proposed by Hirschleifer (1983) but has not previously been experimentally explored in a repeated setting with four players (previous work focuses only the two-person sequential version of the game). As with other public goods games, we find deviations from the equilibrium predictions in this game. More detail on the experimental results from this game can be found in Appendix I**.** But our most important contribution is to examine conditional cooperation in these three games.

Previous work on conditional cooperation focuses almost exclusively on the VCM, both in the laboratory and in the field. Like that work, we find the existence of conditional cooperation, and that in linear public goods settings individuals are most responsive to the median contribution of others. We extend this stream of research to examine conditional cooperation in the WLM and the BSM as well.

In the WLM, we find individuals act consistently with conditional cooperation, but that they are reciprocal not with the average contribution of others but with the minimum contribution of others. In the BSM, we find individuals´ contributions are *negatively* related to the maximum contribution of others. This is consistent with conditional cooperation as when others give more, one´s own contributions are wasted, both personally and socially. Thus both self-interest and conditionally cooperative preferences drive the negative relationship.

Our demonstration of asymmetric conditional cooperation in different games has important implications for explaining and predicting behavior in these settings. For example, while conditional cooperation can drive behavior away from equilibrium in the VCM (toward positive contributions), it can drive behavior *toward* equilibrium in the WLM (toward symmetric contributions) as individuals match the minimum contributions of others. Thus the previously-maintained assumption that conditional cooperation explains deviations from equilibrium may be true only in certain settings. In some settings (like the WLM, for example), conditional cooperation may explain convergence toward equilibrium.

Indeed, if we examine behavior in the WLM, we see some evidence of convergence. Remember that equilibrium behavior in this game means that all participants in a group give the same amount. Thus we can use the within-group standard deviation of contributions as a measure of convergence to an equilibrium: at equilibrium this measure should be zero. We calculate this measure for each group, for each period, and then compare the averages. We find that the average within-group standard deviation of contributions in period 1 is 13.02, while the average within-group standard deviation of contributions in period 10 has significantly reduced to 3.94 (a paired t-test comparing the six independent observations [one for each group] shows this difference to be significant, p=.0069). Thus, over time conditional cooperation pushes behavior in the WLM closer to the equilibrium prediction of symmetric contribution.

In terms of mechanism design (for example, in the voluntary funding of public goods), one might evaluate mechanisms not just on their equilibrium predictions, but also the impact that conditional cooperation is likely to have on the behavior of the constituents. From a more psychological perspective, it is also interesting to see both how sensitive participants in these games are to the behavior of others, and the different ways that sensitivity is actualized. Participants focus not just on any social information, but on the *relevant* social information for their decision (e.g. the minimum in the WLM) and their reactions to that information is again driven by the payoffs of the situation (e.g. negatively in the BSM).

Finally, our evidence suggests some directions for further development of theories of conditional cooperation. Previous work has limited attention to settings, like the VCM, where efficiency is monotonically increasing in cooperation. We believe that in order to have a truly significant impact, the scope of these theories needs to be extended to other situations, and their assumptions and implications worked out for the more general case. We hope that evidence like that presented here will provide some guidance in that direction.

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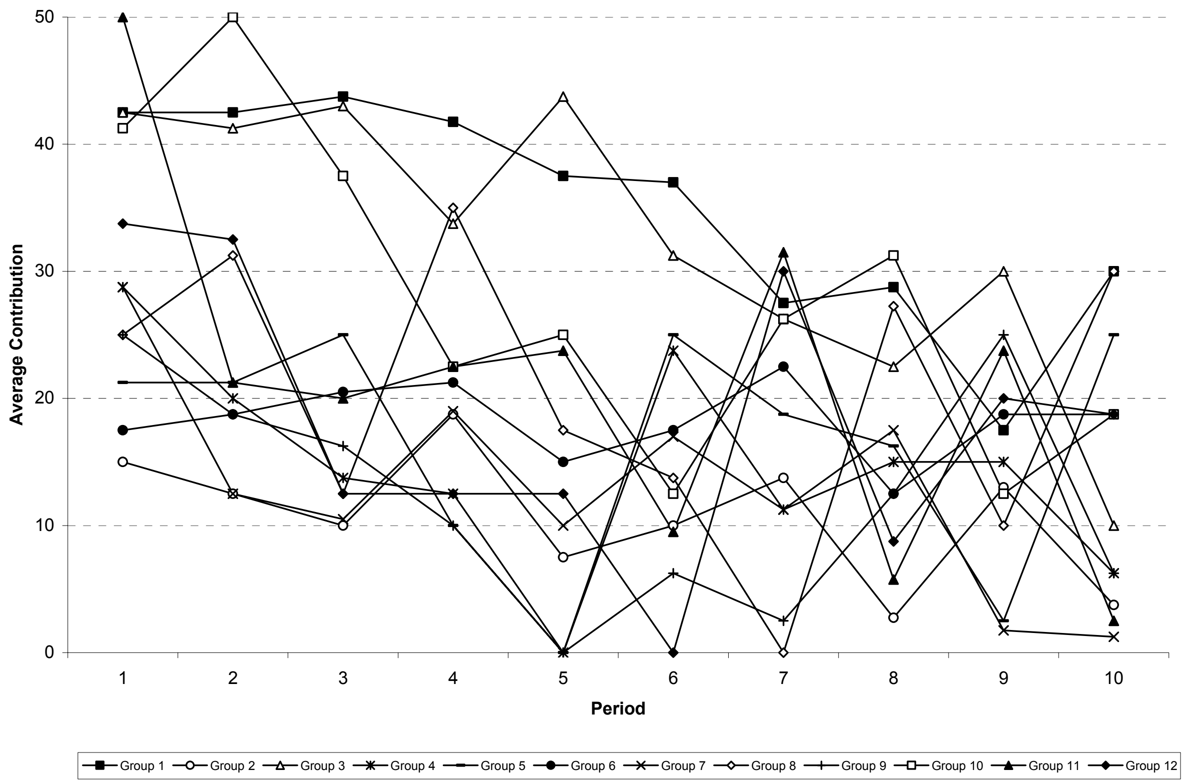
Appendix 1

Since the simultaneous, four-player BSM has not previously been experimentally explored, in this appendix we present some additional detail of behaviour in this game. Figure 1 in the main paper shows the aggregate average contribution in each of the three treatments. Figure 1A here presents average contributions toward the public good for each group in the BSM.

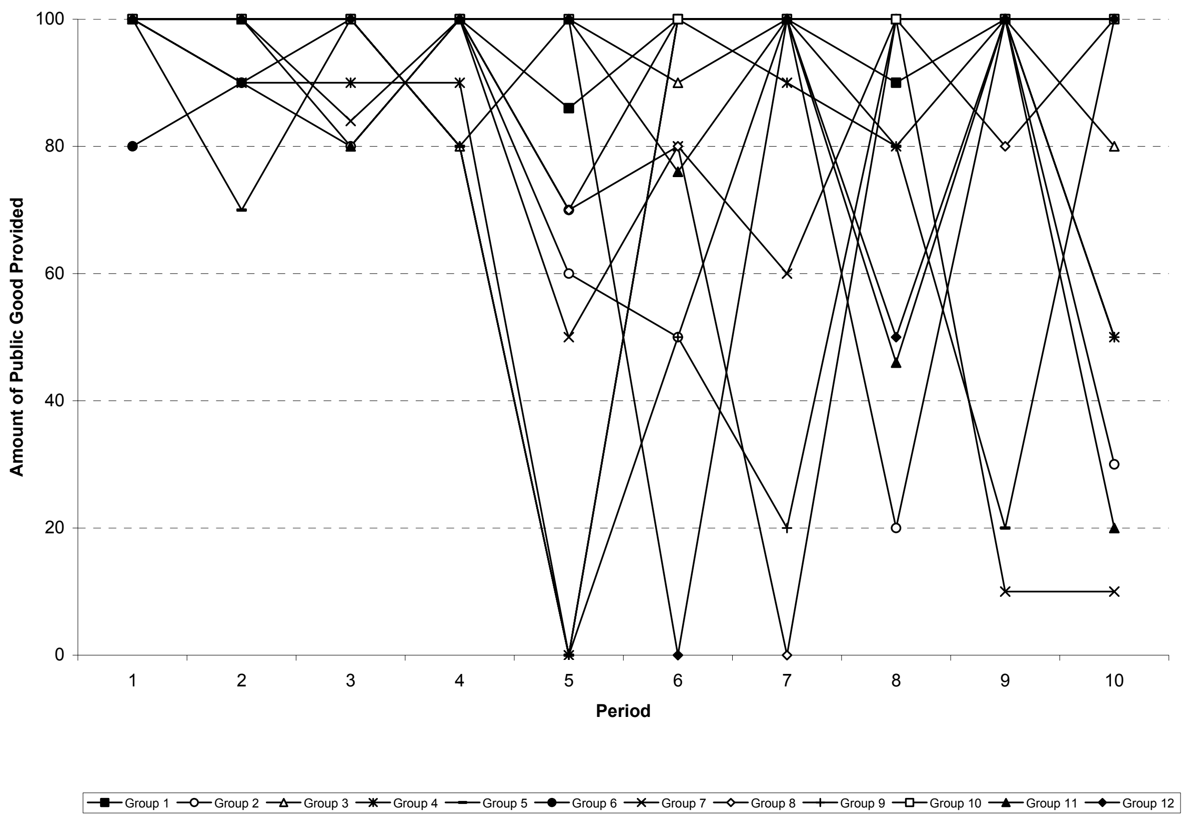
Figure 1A: Average Allocations to the Public Good in BSM by Group



As can be seen here and in aggregate in Figure 1, contributions begin high and then decline over the course of the game. Remember, however, that the amount of public good provided is not sensitive to the average contribution, instead it is sensitive to the *maximum* contribution made by any one individual.

Again, following Figure 2 in the main paper, Figure 2A here shows the amount of public good provided in the BSM disaggregated by each of the 12 groups.

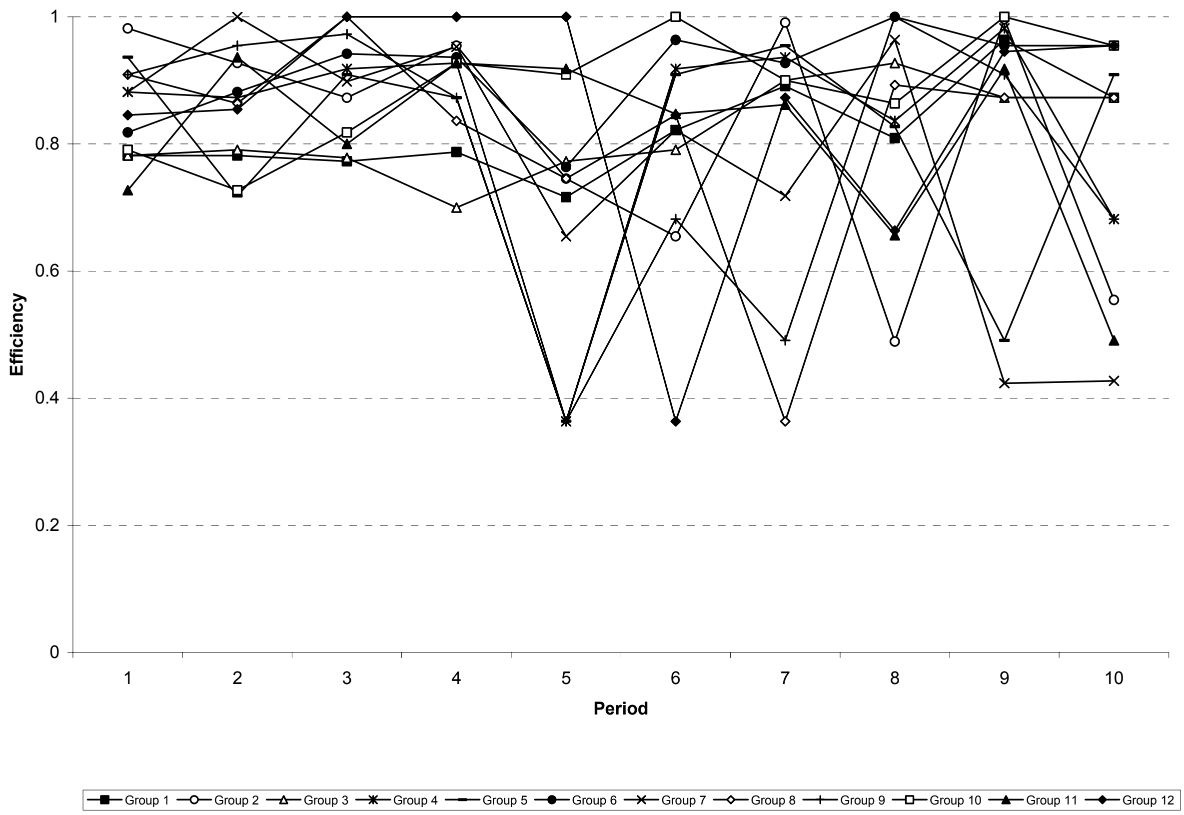
Figure 2A: Amount of Public Good Produced in BSM by Group



Here the picture indicates a coordination difficulty. At the start of the game, at least one individual in each group is prepared to volunteer to contribute maximally or close to it. However, after four rounds or so of this type of contribution, this contributor tries to "hand off" the responsibility to another group member. However, without communication, it is difficult to ensure that another group member will be prepared to pick up the burden, thus causing coordination failure in the second half of the game.

Finally, in Figure 3 we examine efficiency. It is possible, for example, that these high levels of public good production in the first four rounds of the game are due to multiple individuals inefficiently contributing to the public good. Figure 3A shows efficiency percentages (defined as the total earnings of the group divided by the maximum possible earnings) for each group in the BSM.

Figure 3A: Efficiency in the BSM by Group: Percentage of Possible Group Earnings Captured



As can be seen, in early rounds some efficiency is lost due to excess (wasted) contribution. However, the losses in later rounds due to a lack of public good provision far overshadows these initial losses. This result is, of course, sensitive to the parameters we chose. In this particular case, the social cost of wasted contributions is one-half the opportunity cost of having the public good not being provided. Thus the efficiency losses from overcontribution in early rounds are small compared with the efficiency losses from lack of contribution in later rounds.

Do groups learn to play the equilibrium in this game? Using a strict interpretation of equilibrium, the answer must be no. As we have seen in the text, in only 9 rounds out of 120 do groups coordinate on the equilibrium of {0, 0, 0, 50}. However, a looser definition may be in order. For example, consider a contribution profile {0, 0, 0, X}. While not strictly speaking an equilibrium this profile captures only a single player´s deviation from it (giving X instead of giving 50), and thus signals at least some understanding of the game.

Table 1A categorizes the group´s contributions based on the number of individuals contributing zero.

Table 1A: Number of Individuals in Group Contributing Zero

	Period 1 (out of 12)	Period 10 (out of 12)	Whole Game (out of 120)
4	0	0	5
3	0	6	27
2	4	4	46
1	4	2	26
0	4	0	16

In equilibrium and close to it, we expect to see exactly three individuals contributing zero in each period. In period 1 this occurs in none of the 12 groups. However, by the end of the game (Period 10) half of the groups (6 out of 12) have arrived at an allocation involving three zero contributions. A t-test of proportions confirms that these ratios are significantly different from each other (t=11, p<.0001). Over the game as a whole, 22.5% of the observations fall into this category.

Finally, for the interested reader, Table 2A presents the full dataset. We have highlighted the 9 observations at the equilibrium (bold) and the further observations involving close-to-equilibrium behaviour of {0, 0, 0, X} mentioned above (italics). Additionally, we have identified a second close-to-equilibrium outcome, of {0, 0, X, 50} (underlined). Like the above, this contribution profile represents only a one-player deviation from equilibrium (here, the player giving X when they should be giving 0). We believe that this deviation may serve as a kind of insurance against the full-contributing subject deciding it is time for someone else to have a turn at giving. This behaviour is also relatively common, observed 28 out of 120 trials in our game. Thus we have 9+18+28=55 out of 120 (46%) of observations either at equilibrium or only one deviation away.

In sum, we find that the BSM results in high contributions and relatively high efficiency, especially compared with the VCM and WLM games in the text. However, participants´ play is quite far from the equilibrium, and even once a group reaches the equilibrium they are unlikely to stick there.

These results can be compared with results examining the BSM in sequential settings (Harrison and Hirschleifer 1989, Prasnikar and Roth 1992, Duffy and Feltovich 1999, Andreoni et al. 2002, Carpenter 2002), where coordination is significantly easier. We find that in our setting, when the strategy space and the number of players are large and when the game is played simultaneously without signals for coordination, behaviour is quite far from the equilibrium. However, this mechanism still results in remarkably efficient outcomes, relative to the VCM and the WLM.

Table 2A: Individual Contributions, Best Shot Mechanism

	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	01	02	03	04	11	12	13	14	21	22	23	24
	0	0	0	0		0		0	0	0	0	0	0	0	5				5	0	0			0	0	0	5		0			0	0	5		5	0	5	0	0	0	0	0	0	5	0	0	
	5	0	5	0				5	0	0	0	5	5		5		5		5	5	0			5		**0**			0	5		0	0	5			0	0	0	0	5	0			0	0	0	
	5	0	0	0				*0*	0	0	0	2	5		0		0	5	5		2			0			*2*					**0**	0	5			0	0		0	0	0					**0**	
	0	0	7	0		5		0	0	0	5	0	5						*0*		5			0	0	5	1		0	0		0	*0*				0	0			0	0					**0**	
	0	0	3	7				*0*	0	0	5	0									5			5		5	5		5			5						0		0	5		0				**0**	
	3	0	5	0		5		5	5	0	5	5	5		0			5	5	0	0			0	5	0					5	0	*5*					**0**			*8*							
	0	0	0					0	5	0		0	*5*				5			0	0			0	5		0							*0*			5	0		0	6	0		0	0	0	0	
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		0	0		0				0	0		0			0	0			*0*		5			0								*0*	0	0				**0**			0	5	0		0	0	0	
0	0	0		0		*5*						*0*			*5*		0			0	5			0					0	5		5	*5*					5		0	*0*					0	5	

Bold: Equilibrium (9/120)

Italics: Three contributions of zero, one contribution less than 50 (18/120)

Underline: Two contributions of zero, one contribution of 50 (28/120)