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Conditional vs. Voluntary Contribution Mechanism – An Experimental Study

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Abstract

The Conditional Contribution Mechanism for public good provision gives all agents the possibility to condition their contribution on the total level of contribution provided by all agents. In this experimental study the mechanism's performance is compared to the performance of the Voluntary Contribution Mechanism. In an environment with binary contribution and linear valuations subjects play the mechanisms in a repeated setting. The mechanisms are compared in one case of complete information and homogeneous valuations and in a second case with heterogeneous valuations and incomplete information. In both cases a significantly higher contribution rate can be observed when the Conditional Contribution Mechanism is used.

Keywords: Experimental Economics, Public Goods, Mechanism Design, Better Response Dynamics.

JEL-Classification: C9, D82, H41, C72

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1 Introduction

Numerous attempts have been made to solve the free-rider problem in public good environments. While there are many complex mechanisms that have good theoretical properties, it is exactly this complexity that makes them difficult to apply in practical applications. However, the simple mechanisms which are mostly used, like e.g. the Voluntary Contribution Mechanism (VCM), do not have good theoretical properties and suffer, at least to some extent, from the free-rider problem. With the recent development of the Binary Conditional Contribution Mechanism (BCCM) there is a new simple candidate to solve the free-rider problem (Reischmann, 2015). This paper presents the first experimental evidence on the performance of the BCCM.

This special case of the class of Conditional Contribution Mechanisms (CCMs) is applicable in binary contribution environments. It extends the message space of the VCM {"Contribute", "Don't Contribute"} by conditional contribution offers of the form "Contribute only if at least k other agents contribute as well". The mechanism is played simultaneously by all agents. When there are multiple outcomes that satisfy all conditions, the mechanism selects of these outcomes the one with the largest amount of total contributions.

The CCMs are designed with a focus on dynamic properties. Thus, the static equilibrium properties are not very impressive. The CCMs have many efficient, but also many inefficient Nash equilibria. However, Reischmann (2015) applies a variant of Better Response Dynamics under which all outcomes of dynamic steady states are Pareto efficient. Since Healy (2006) shows that Better Response Dynamics describe subject behavior in public good games rather well, the BCCM is well suited for repeated public good environments.

The aim of this experimental study is to evaluate whether the BCCM is a suitable candidate to solve the free-rider problem. For this sake, I compare the BCCM with the VCM. The VCM is chosen as a comparison since it is, besides the Provision Point Mechanism (PPM), the only mechanism that is regularly applied in practical applications. Further the PPM is better suited for step-level public goods, which are not the focus of this study. Thus, the

VCM is still the most important benchmark to beat.

Both the VCM and the BCCM are tested in two repeated public good environments, one with complete and one with incomplete information. In both treatments I find the effect, that the BCCM produces significantly higher contribution rates than the VCM. As expected from the theoretical analysis the difference in contribution rates is mainly found in the last 10 periods. This result supports the theoretical prediction that the BCCM sets better dynamic incentives in repeated public good environments than the VCM.

1.1 Related literature

My work mostly relates to two kinds of literature, first experiments comparing the performance of two or more public good mechanisms and second experimental studies on behavior in public good mechanisms in general, or the Voluntary Contribution Mechanism in particular.

Smith (1979, 1980) compares his auction mechanism to the VCM and a quasi-free-rider mechanism. All three mechanisms have in addition an unanimity rule. If an outcome is not unanimously accepted no contribution will be made to the public good. Smith finds that the auction mechanism supplies significantly higher levels of the public good as the free rider quantity. However, if the cases when unanimity fails are taken into account the auction mechanism does not perform significantly better than the alternative mechanisms. Banks et al. (1988) continue the investigation of the auction mechanism and compare it to the VCM. They compare both mechanisms with and without unanimity. They find that the auction mechanism is more efficient than voluntary contribution. Unanimity seems to lower contributions overall.

There are multiple studies comparing the VCM with a Provision Point Mechanism (PPM). Rondeau et al. (1999) show that under specific conditions the PPM can be demand revealing. Building on this Rondeau et al. (2005) find that the PPM leads in a lab and a field experiment to a higher willingness to contribute to the public good than the VCM. Rose et al. (2002)

further study the PPM in a field experiment on green energy and find that contribution rates outperform previous studies that used the VCM. However, every contribution in the VCM can definitely be used to finance a certain level of the public good. Contributions under the PPM might be lost for the public good if the threshold for provision was chosen too high.

Further mechanisms that have recently been tested experimentally are auction and lottery mechanisms. Schram and Onderstal (2009) compare a first-price winner-pay auction, a first-price all-pay auction and a lottery. They find that out of those three mechanisms the all-pay auction leads to significantly higher contributions. Morgan and Sefton (2000) present an experiment in which a lottery leads to higher contribution to a public good than the VCM. They further find that higher price money leads to a more effective mechanism. Contrary to the findings of Schram and Onderstal (2009), Corazzini et al. (2010) show an experiment in which a lottery outperforms an all-pay auction. Still in their experiment both mechanisms fare better than the VCM.

Behavior in public good environments under the Voluntary Contribution Mechanism is very well understood. Early experiments find consistently that contribution rates are around half-way between the efficient and the free-rider quantity in one-shot games. Under repeated interaction these contributions decline over time. See Ledyard (1994) for a survey on this branch of the literature. The more recent experiment by Burger and Kolstad (2009) covers VCM treatments with binary contributions and they find results in the same spirit, medium contribution rates in the first period and a decline of contributions over time.

By now economic theory can explain these findings that contradict the strong free-rider hypothesis. One explanation is given by social preferences, as e.g. the model of inequality aversion by Fehr and Schmidt (1999). Another explanation are preferences for conditional cooperation as found by Fischbacher et al. (2001). In combination with the finding of Healy (2006) that agents better respond in public good environments this explains positive contributions in the first period as well as the decline over time.

The rest of the paper is structured as follows. Section 2 introduces the two mechanisms that will be covered in the experiment. In section 3, there is a short theoretical analysis of the equilibrium properties of those mechanisms. Section 4 covers the description of the experimental setup, while section 5 presents the results. Finally, section 6 gives a short summary and discussion of the paper. Translations of written instructions and test questions handed out to subjects in the experiment can be found in the appendix.

2 Environment and mechanisms

In this experimental study I compare two different mechanisms. Both mechanisms are tested in an environment with five agents. Those agents play one of the mechanisms as a stage game repeated over 20 periods. In every period the agents are endowed with 10 points.[1] Those points can be invested in a group project or be kept in the private account. The points can not be divided between the two options, so contribution is binary. In the following section an outcome is going to be described by $z = (z_1, z_2, z_3, z_4, z_5)$. $z_i = 0$ denotes that agent i does not invest his points into the project and $z_i = 10$ implies that he does invest his points into the project.

The two mechanisms are compared in two different cases. One case with complete information and homogeneous valuations and one with incomplete information and heterogeneous valuations. Comparisons between the two cases with the same mechanism are not the focus of this study.

In the complete information case every agent knows all players' valuations for the public good and valuations are homogeneous with $\theta_i = 0.6$. In the incomplete information case agents only know their own valuation and all agents have a valuation of $\theta_i = 0$ with a probability of 20% and a valuation of $\theta_i = 0.6$ with probability of 80%. Thus, heterogeneous valuations are possible. The first type of agents, who do not benefit from the public good, are called type 1 agents. And agents, who do benefit, are called type 2 agents. The draws

[1] 10 points are chosen to ensure that the number of points earned in each period is a natural number in all cases.

of valuations for group members are independent. Every draw is used though for one group with each mechanism to ensure comparability. Given their valuation agents have the following payoff function:

$$\Pi_i = 10 - z_i + \theta_i \sum_{j=1}^{5} z_j \tag{1}$$

In the Binary Conditional Contribution Mechanism (BCCM) agents can condition their contribution on a total level of contribution provided by all agents. The message space is given by $M_i = \{0, 1, 2, 3, 4, 5\}$. Message $m_i = k$ can be interpreted as saying "I'm willing to contribute to the public good if at least k other agents contribute as well." Message $m_i = 0$ is equivalent to contributing in any case. And the message $m_i = 5$ is equivalent to contributing in no case.[2] An offer for conditional contribution can be satisfied it two ways. Either the agent does not have to contribute. Or his condition for contribution is satisfied. This implies that for a given message profile m there might be more than one outcome z that satisfies all conditional contribution offers. Of all those outcomes the BCCM selects the one with the highest total level of contribution. This can be formalized by using the following help variable:

$$K(m) := \max \left\{ k \in \{0, 1, ..., n\} \middle| \sum_{i=1}^{n} \mathbb{1}_{(m_i < k)} \geq k \right\}, \tag{2}$$

where $\mathbb{1}_{(m_i<k)}$ denotes the indicator function, which is 1 if $m_i < k$ and 0 otherwise. With this variable, the outcome of the mechanism can be defined as $g^{BCCM}(m) = z$ with $z_i = 10$ if and only if $m_i < K(m)$.

Example 2.1 *Consider the following examples. If all agents choose $m_i = 5$, no agent contributes to the public good. If all agents choose $m_i = 4$, there are two outcomes that satisfy all conditions. In the outcome $z = (10, 10, 10, 10, 10)$ all agents contribute to the public good. And in the outcome $z = (0, 0, 0, 0, 0)$ no agent contributes to the public good. Therefore,*

[2] Since there are only 5 agents in total, there can never be more than four other contributing agents.

the BCCM selects the first outcome and all agents will have to contribute. Similarly if e.g. $m_1 = m_2 = m_3 = 2$, $m_4 = 4$, $m_5 = 5$, *then agents 1, 2 and 3 will contribute to the public good.*

The mechanism that I use as a benchmark is a standard binary Voluntary Contribution Mechanism (VCM). In this mechanism agents have only two options. They can contribute in any case or free-ride in any case.

3 Theoretical predictions

For an extensive analysis of the theoretical predictions of the general Conditional Contribution Mechanisms I refer to the companion paper (Reischmann, 2015). Here I analyze the predictions for the specific versions of the mechanisms used in the experiments.

Two different solution concepts will be considered. The first one is Nash equilibrium, since it is the most standard concept and it provides intuition about what might be stable outcomes of the mechanisms. The second one is Unexploitable Better Response Dynamics. This is a variant of Better Response Dynamics which is developed and motivated in the companion paper mentioned above.[3] The definition is as follows:

Definition 3.1 *Given a message profile* m *and an outcome* $g(m) = z$, *a deviation from* m_i *to* m'_i *is called exploitable if there exists* $m_{-i} \in M_{-i}$ *such that* $z'(m_{-i}) := g(m'_i, m_{-i}) \prec_i z$ *and* $z'_i(m_{-i}) > 0$. *A message* m'_i *is called unexploitable, if it is not exploitable.*

Definition 3.2 *In Unexploitable Better Response Dynamics (UBRD) all agents can adjust their message in every period. Agent* i *switches in period* t *to message* m_i^t *with strictly positive probability if and only if*

- m_i^t *is a (weak) better response to* m^{t-1} *and*

[3] UBRD is only supposed to capture all relevant long term incentives of the Conditional Contribution Mechanisms. Thus, the concept wants to make a good prediction about what outcomes occur in dynamically stable states of the CCM. The concept is not intended to describe agents short term behavior in detail. Nor is it intended to be applicable to other mechanisms.

- *m_i^t is unexploitable with respect to $z^{t-1} := g(m^{t-1})$.*

Summarizing the motivation given in Reischmann (2015), UBRD makes the following two assumptions on long term incentives. First, in the long term agents do not choose messages that make them worse off immediately. This is captured by the better response condition. Second, agents do not choose messages that make outcomes possible, in which the agent has to contribute to the public good, but is worse off than in the current outcome. This is captured by the unexploitability condition.

Since this is an experimental study, the experimental results will present a good opportunity to evaluate the validity of this concept. Thus, the discussion whether UBRD is a reasonable solution concept for this mechanism is postponed to section 5, where the experimental results are discussed.

3.1 Voluntary Contribution Mechanism

The Voluntary Contribution Mechanism gives every agent the choice whether he wants to contribute to the public good. And no agent has any influence over any other agent's contribution. Disregarding social preferences, it is easy to see, and well known in the literature, that free-riding is a dominant strategy here. This is true for all agents with a valuation $\theta_i < 1$. The straight forward Nash prediction, not taking possible social preferences into account, is thus that all agents will free-ride. Since free-riding is a strictly dominant strategy any refinement of Better Response Dynamics will also predict this outcome as a unique steady state.

However, it is equally well known that this theoretical prediction is seldom to never observed in experiments. Indeed the general observation is a contribution rate of about 40-60% of the efficient level in the first period. If the public good game is played repeatedly, as it is in this study, the typical experimental finding is that contribution rates decline over time. Social preferences (Fehr and Schmidt, 1999) as well as preferences for conditional cooperation (Fischbacher et al., 2001) in combination with a better responding behavior (Healy, 2006) explain these findings well. Since those findings are very persistent (see Ledyard (1994) for a survey of the early findings and Burger and Kolstad (2009) for a recent example with the binary VCM), this is also what I expect to find in this experiment.

3.2 Binary Conditional Contribution Mechanism

Reischmann (2015) proves that any outcome of the BCCM is the outcome of a Nash equilibrium if and only if it is a weak Pareto improvement over $\underline{z} := (0, 0, 0, 0, 0)$. This is easy to see for the specific case considered in the experiment. Consider the outcome $z = (10, 10, 10, 0, 0)$ in the complete information treatment ($\theta_i = 0.6 \ \forall \ i = 1, \ldots, 5$). This is a Pareto improvement over $\underline{z}$. One Nash equilibrium that leads to this outcome is given by $m_1 = m_2 = m_3 = 2$, $m_4 = m_5 = 5$. All other Pareto improvements z over $\underline{z}$ are supported as Nash equilibrium in similar fashion. Agents who contribute in z condition their contribution on the total level of contribution in z and all other agents choose to contribute in no case.

Thus, the Nash prediction in the homogeneous case would be that either none, two, three, four, or all five subjects contribute in any group. This, of course, is no useful prediction since it only excludes outcomes in which one subject contributes alone. Unexploitable Better Response Dynamics, however, predict convergence to either an outcome in which all five subjects contribute ($m = (4, 4, 4, 4, 4)$), or an outcome in which four agents contribute ($m = (3, 3, 3, 3, 5)$, in any permutation). Note that these are exactly the outcomes which are Pareto efficient in a non-transferable utility framework.

The formal proof that the stable outcomes of the BCCM under UBRD coincide with the Pareto efficient allocations, which are Pareto improvements over $\underline{z}$, can again be found in the companion paper. Here I provide some intuition with another example.

Example 3.3 *Assume that the current message profile is* $m = (3, 3, 3, 3, 5)$*. In this case only agent 5 does not contribute to the public good. Thus, the outcome is* $z = (10, 10, 10, 10, 0)$*. Any deviation of agent 5 will lead to an outcome in which he has to contribute to the public good. This would not be a better response. If any one of agents 1 through 4 switches to a* *message* $m_i \in \{4, 5\}$ *the outcome would be* $\underline{z}$*. Those messages are not better responses either. Any message* $m_i \in \{0, 1, 2\}$ *violates the unexploitability condition since it makes outcomes possible in which the agent must contribute but is worse off than in the current outcome. Take e.g.* $m_1 = 2$*. This makes the message profile* $m = (2, 2, 2, 5, 5)$ *possible. In this profile agent* 1 *has to contribute and total contributions are lower than in the other outcome. Thus, the message profile* $m = (3, 3, 3, 3, 5)$ *is one steady state of UBRD.*

The next example demonstrates why outcomes that are not Pareto efficient can not be steady states of UBRD.

Example 3.4 *Assume that the current message profile is* $m = (2, 2, 2, 5, 5)$*. In this case agents 1,2 and 3 contribute to the public good. Thus, the outcome is* $z = (10, 10, 10, 0, 0)$*. No agent can directly benefit from any deviation. Thus, the message profile* m *is a Nash equilibrium. However, agents 4 and 5 can deviate to the message* $m_i = 4$*. One such deviation does not change the outcome and a unilateral deviation is thus a weak better response. Further, agents 4 and 5 will only have to contribute to the public good if the outcome will be* $z' = (10, 10, 10, 10, 10)$*. Agents 4 and 5 are both better off in* z' *than in* z*. Thus, the message* $m_i = 4$ *is unexploitable. However, if both agents 4 and 5 switch to* $m_i = 4$ *the outcome will indeed be* z'*. Therefore,* m *is not a steady state of UBRD.*

The equilibria in the incomplete information treatment mirror the results of the complete information case. Since the dynamics only consider the heterogeneity part of the incomplete information treatment this is not surprising. Thus, in this treatment either all or all but one type 2 agents are predicted to contribute. Still, all outcomes of steady states are Pareto efficient.

4 Experimental design

The experiments were conducted at the Alfred-Weber Institute of Heidelberg University. The subject pool used for recruiting consists mainly of students. In each session 10, 15 or

20 subjects participated in groups of 5. In total 195 subjects took part in the experiments. Seven groups played the VCM with complete information and eight groups played the BCCM with complete information. In the incomplete information treatment each mechanism was played by 12 groups. Sessions lasted between 45 minutes and one hour.

When the subjects entered the lab they were randomly allocated to their seats by drawing numbered cards. Every subject was then handed one set of instructions and test questions. English translations of the instructions and test questions can be found in Appendix A and B. Once all subjects answered the test questions correctly and there were no more questions a computer program written in z-Tree (Fischbacher, 2007) was started. The program randomly matched subjects in groups of 5. Groups stayed the same over all 20 periods. Every group played only one mechanism and only one information treatment. In the incomplete information treatment the random draw of types was performed by the program at the beginning of period one.

After the last period there was a short questionnaire asking for personal characteristics such as gender and previous knowledge of game theory. Afterwards subjects were called by seat number to receive their payoff in private. In every period subjects could earn between 6 and 30 points. Points of all periods were added up. Subjects were payed 1€ for every 40 points. Type 1 subjects in the incomplete information treatment received an additional 5€ to compensate them for the lower earning possibilities. Average earnings per subject were 11.55€.

5 Experimental results

This study intends to answer two questions. First, is the BCCM suited to improve contribution rates to public goods compared to the VCM? Second, is the model of UBRD suited to predict long term stable outcomes of Conditional Contribution Mechanisms?

5.1 Contribution rates

Whether or not the BCCM can increase contributions to the public good significantly compared to the VCM is the primary question. Therefore, I compare total contributions in groups under the BCCM to those contributions under the VCM using the Wilcoxon-Rank-Sum Test. In each group I take the average of total contributions over a certain number of periods. First, I consider all periods to get an impression of the total effect. Second, I only consider the last 10 periods, to get an impression of the long term effect, once a certain level of convergence has taken place including the endgame effect. Third, I consider periods 9 to 18. This choice makes it possible to look at the long term effects excluding the end game effect.

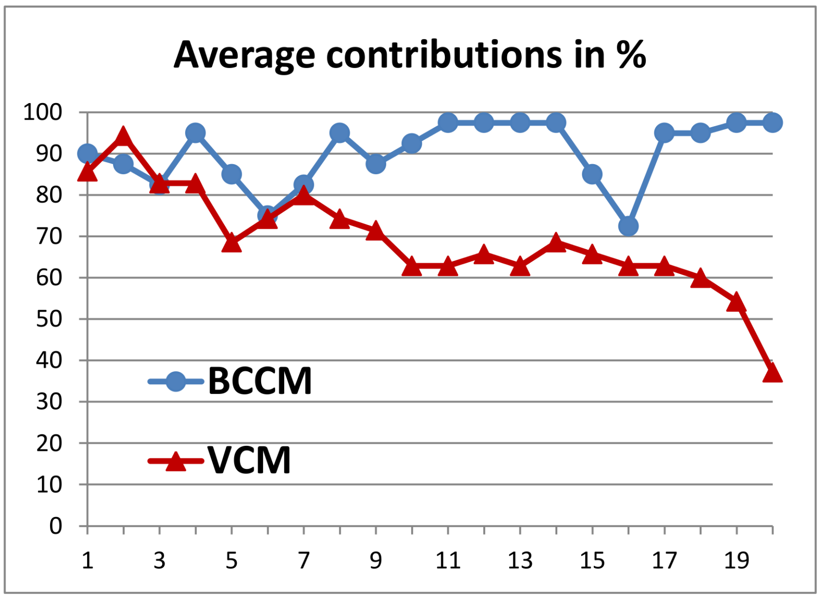

Figure 1: Comparison of average contributions over all groups in the complete information treatment.

Average contributions per period over all groups with complete information are displayed in figure 1. The figure makes the following immediate observations possible. First, the contribution rate in the first period under the VCM is surprisingly high. The reason for this is probably the binary contribution environment in combination with the rather small group size of 5. Second, contributions in the VCM decline over time as expected. Third,

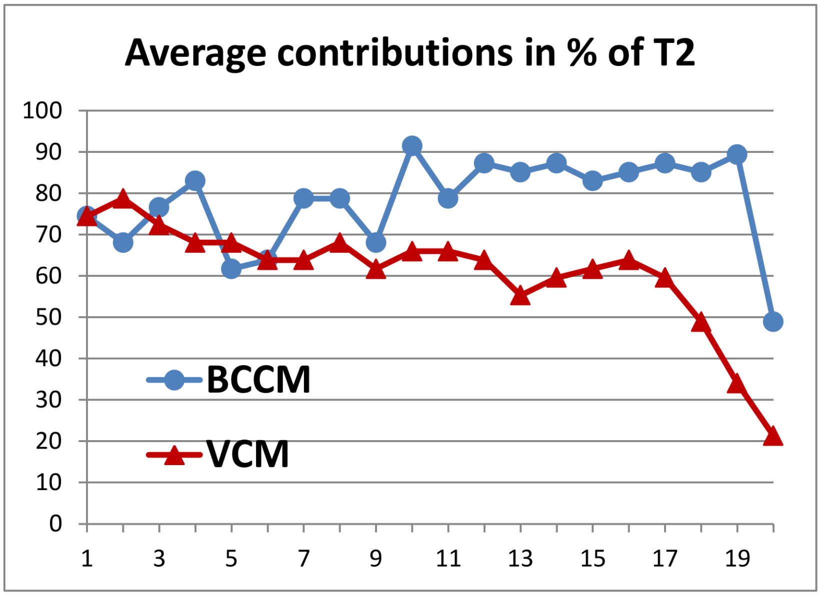

Figure 2: Comparison of average contributions over all groups in the incomplete information treatment.

contribution rates in the BCCM are similar to the VCM in early periods but much higher in the later periods. Fourth, the BCCM does, in this treatment, not suffer from any endgame effect. All these observations support the theoretical prediction that the BCCM has better dynamic properties than the VCM. In fact the BCCM leads already to significantly higher contributions when all periods are taken into account ($p = 0.0425$). When only the last 10 periods are considered the effect is highly significant ($p = 0.0080$). And when I exclude the endgame effect (periods 9 to 18) the results are still significant ($p = 0.0388$).

In the incomplete information treatment type 1 agents have a dominant strategy to free-ride. Besides a few mistakes in period 1 and one mistake in period 2 all subjects also chose this strategy. Therefore, contribution rates in the incomplete information treatments are always compared in terms of average contributions of type 2 agents. Average contributions of type 2 agents per period over all groups with incomplete information are displayed in figure 2. The observations from this figure differ from the complete information case in only one way. Under incomplete information the BCCM suffers from a severe endgame effect. There are two reasons for this. Some agents harm themselves by deviating because they try to

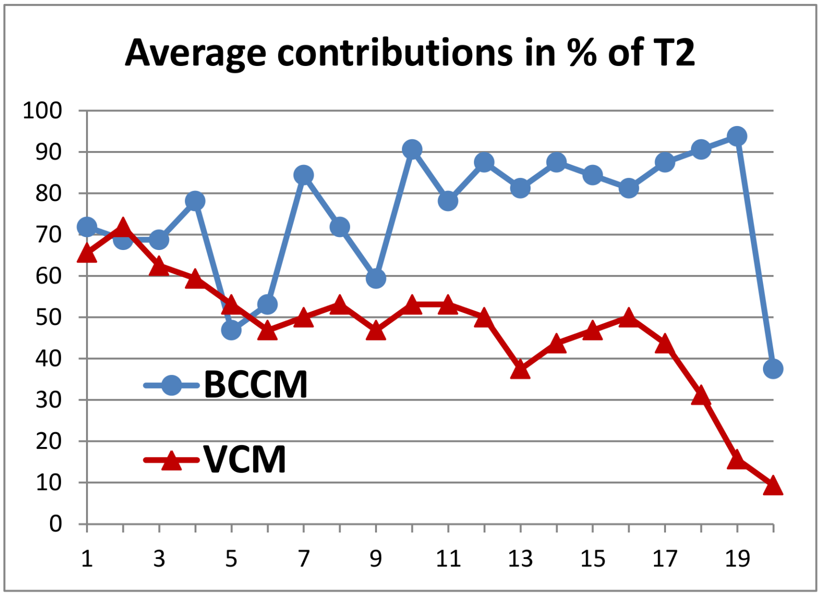

Figure 3: Comparison of average contributions over all groups with at least one type 1 agent.

free-ride in a coordinated equilibrium resulting in a complete breakdown of contributions. My only explanation for this behavior is that some agents make mistakes, because of the somewhat higher complexity of the incomplete information treatment. The second reason is that some groups reach Pareto efficient outcomes, but no stable equilibrium by period 20. This creates incentives for individual agents to deviate. However, more than one deviation usually leads again to a complete breakdown. This makes the endgame effect even bigger than in the VCM treatments. This second effect might vanish when more periods are played, which gives subjects more time to converge to stable equilibria. Besides this point, however, the results are very similar. The increase in contributions when all periods are considered is at least weakly significant ($p = 0.0602$). For the last 10 periods results are again significant at the 1% level with a p-value of $p = 0.0078$. And when the last two periods are excluded the increase is significant at the 5% level ($p = 0.0199$).

Figure 3 shows the average contribution rates when in the incomplete information treatments only those groups are considered that contain at least one type 1 agent. This leads to lower contribution rates under both mechanisms in the first half of the experiment. However, groups playing the BCCM manage to achieve the same high contribution rates in periods 10 to 19. Groups playing the VCM however can not stop the decline of contributions. This observation strengthens the impression that the BCCM robustly reaches high long term contribution rates even in settings in which coordination in the early periods is difficult.

Result 5.1 *Under complete as well as under incomplete information the Binary Conditional Contribution Mechanism leads to higher contribution rates than the Voluntary Contribution Mechanism.*

The theoretical analysis further suggests that the BCCM should be able to reach stable equilibria with high contribution levels. If this is true it should not be possible to find a decrease in contributions over time as has repeatedly been shown for the VCM. In fact since failed coordination in the early periods might lead to low contribution rates in those periods the BCCM might lead to an increase of contributions over time. Therefore a Wilcoxon Matched-Pairs Signed Rank Test is used to compare average contribution rates over the first 10 periods with those over the last 10 periods.

In both treatments with the Voluntary Contribution Mechanism contributions in the first 10 periods are significantly higher than in the last 10 periods. The p-values are given by $p = 0.0343$ for complete information and $p = 0.0022$ for incomplete information.

In the BCCM treatments on the other hand I observe higher contribution rates in the last 10 than in the first 10 periods under complete information with a p-value of $p = 0.0193$. And under incomplete information the hypothesis that contribution rates in the first and last 10 periods are equal can not be rejected ($p = 0.3668$).

Result 5.2 *In treatments with the Voluntary Contribution Mechanism contributions decrease over time. In treatments with the Binary Conditional Contribution Mechanism this is not the case. Under complete information contribution rates are even increasing.*

One typical goal of the implementation problem is that the designed mechanism should lead to Pareto efficient outcomes. Whether the BCCM leads to Pareto efficient outcomes can only be answered qualitatively. In the case of complete information when all periods are considered 91.88% of outcomes are Pareto efficient. When only the last 10 periods are taken into account 96.25% of outcomes are efficient. And in the last 4 periods every single outcome is Pareto efficient. Note again that Pareto efficiency is considered without the possibility of transfer payments. Thus, an outcome is Pareto efficient if four or five agents contribute to the public good.

While the theoretical prediction of Pareto efficient outcomes fits the data well in the complete information case the situation differs under incomplete information. In those treatments 75.42% of all outcomes under the BCCM are Pareto efficient. This number increases slightly to 80.83% in the last 10 periods, but decreses again to 75% in the last 4 periods, because of the endgame effect under incomplete information.

Result 5.3 *Under complete information the Binary Conditional Contribution Mechanism converges to Pareto efficient outcomes. Under incomplete information about 3 out of 4 outcomes are Pareto efficient.*

5.2 Unexploitable Better Response Dynamics

Finally, I am interested in the model of Unexploitable Better Response Dynamics itself. How well does the model fit the data for the Binary Conditional Contribution Mechanism?

Note first that the model of better responding agents fits the data pretty well. In the complete information treatment about 93% of messages sent are better responses. In the incomplete information treatment the value is even a little bit higher at 96%, both times high enough to claim that a better responding behavior describes the observations reasonably well. However, only around half of all messages are also unexploitable better responses in the two treatments (41% under complete and 53% under incomplete information).

There is no support for a theory that agents learn to choose unexploitable messages over time under incomplete information (52% of messages are unexploitable better responses in the last ten and 53% in the last 5 periods). And only weak support for a learning towards unexploitablity under complete information (35% in the last ten and 47% in the last 5 periods).

However, Unexploitable Better Response Dynamics is only intended as a concept that predicts long term stable outcomes. As such UBRD predicts that the long term stable outcomes are the Pareto efficient outcomes. If the dynamics are considered to have converged to a stable outcome if at least four out of the last five outcomes are identical then, 14 out of 20 groups converge to an outcome. Of those 14 outcomes all 14 are Pareto efficient. This supports the conclusion that UBRD predicts the dynamically stable outcomes of the BCCM correctly. In comparison, under the definition of convergence from above, 8 out of 19 groups under the VCM reach a stable outcome. Of those 8 outcomes 4 are Pareto efficient and 4 are not Pareto efficient.

6 Summary and discussion

In this work an experiment was conducted with the aim to test the performance of the Binary Conditional Contribution Mechanism (BCCM) for public good provision. Since this is the first test a simple binary contribution environment with linear valuations is chosen. In the experiment the BCCM is compared to the standard Voluntary Contribution Mechanism in one setting with complete and one with incomplete information.

In all settings the BCCM leads to significantly higher contribution rates than the VCM. This effect is especially large if only the second half of the experiment is considered. In those periods convergence in many groups of the BCCM is complete and average contribution rates are rather stable at 93% (complete information) or 81% (incomplete information). By comparison, average contribution rates over the same periods under the VCM are 60% (complete information) and 53% (incomplete information). Another important difference between the mechanisms is that in groups playing the BCCM no decline of contributions over time can be observed.

This experiment further gives support for the dynamic model Unexploitable Better Response Dynamics designed in Reischmann (2015). The model gives an accurate prediction of the long term stable outcomes of the BCCM in the test environment. And all those outcomes are Pareto efficient.

With the apparent experimental success of the BCCM the non-binary Conditional Contribution Mechanism should be tested soon in a follow-up experiment. Thus, next tests should focus on non-binary and/or non-linear environments. Considering the intuitive appeal and simplicity of the message space the Conditional Contribution Mechanisms are further suited to be tested in field experiments.

The BCCM is a new mechanism for public good provision that satisfies individual rationality and incentive compatibility. Furthermore, the mechanism is, compared to many other existing mechanisms, rather simple. With the success of the BCCM in this experimental study it becomes a candidate to finally solve the free-rider problem in a fitting class of public good environments.

Appendix A

This Appendix covers the experiment instructions. They are translations from the German original. The German version can be obtained on request from the author. The different instructions for the four treatments are given in the following order: 1.) VCM, complete information, 2.) CCM, complete information, 3.) VCM, incomplete information 4.) CCM, incomplete information.

6.1 Instructions for VCM with complete information

Instructions

Welcome to our experiment! Please read the instructions carefully. Do not talk to your neighbor from now on. Shut down your mobile phone and keep it turned off until the experiment ends. If you have any questions, raise your hands. We will come to you. All participants have got the same instructions.

In the experiment you will be divided in **groups of 5**. The experiment will last for **20 periods**. You will be grouped with the same four players in all periods. The experiment is entirely anonymous. No player will be informed whom he was grouped up with or what payoff any other player obtains.

Points are the currency in the experiment. In every period you start with 10 points. These points will by the end of the period either be added entirely to your private account, or will be invested entirely into a common project. For every player who invests his **10 points** into the project all players obtain **6 points**.

Example 1: You invest you 10 points into the project and 2 other players invested into the project additionally. You will get for your investment and for the investment of the other 2 players 6 points each. Thus you will get $3 \times 6 = 18$ points in total added to your account.

Example 2: You do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get additionally 6 points each for the investment of the other 2 players. Thus you get $10 + 2 \times 6 = 22$ points in total added to your account.

Every player can choose in every period between two actions:

- You can invest your 10 points into the project.
- Or you can keep your 10 points for yourself.

All players decide simultaneously.

Payoff of all periods

After it was determined who contributes to the project in a given period, all players get the corresponding points added to their account.

Then a new period starts. After 20 periods there will be a questionnaire. After the experiment you will be called to receive your money. You will receive your **earnings for all periods** at a rate of 40 points=1€. The payment will be private and in cash.

Program structure

You obtained a printed example for the structure of the program, which you will use to submit your decision in every period. The screen is divided into three blocks.

The block on the upper left side contains a calculator. Here you can test actions for you and the four other players. Once you select an action for every player the computer will calculate the payoff you would obtain in this case.

In the upper right block you enter the action that will be relevant for your payoff. Below there is a red button. When you push this button you submit your decision and leave the screen. Only when **all** players pushed the button the experiment continues. A clock on the upper right hints at the time in which your decision should be made. **If the time runs out this has no effect.**

From period two on the actions of all players of all previous periods and your payoff in those periods will be displayed in the big block below. In the first period this block will be empty.

The texts in the green frames on the printed example of the program are comments that explain the print. They will not be displayed in the actual program.

6.2 Instructions for CCM with complete information

Instructions

Welcome to our experiment! Please read the instructions carefully. Do not talk to your neighbor from now on. Shut down your mobile phone and keep it turned off until the experiment ends. If you have any questions, raise your hands. We will come to you. All participants have got the same instructions.

In the experiment you will be divided in **groups of 5**. The experiment will last for **20 periods**. You will be grouped with the same four players in all periods. The experiment is entirely anonymous. No player will be informed whom he was grouped up with or what payoff any other player obtains.

Points are the currency in the experiment. In every period you start with 10 points. These points will by the end of the period either be added entirely to your private account, or will be invested entirely into a common project. For every player who invests his **10 points** into the project all players obtain **6 points**.

Example 1: You invest you 10 points into the project and 2 other players invested into the project additionally. You will get for your investment and for the investment of the other 2 players 6 points each. Thus you will get $3 \times 6 = 18$ points in total added to your account.

Example 2: You do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get additionally 6 points each for the investment of the other 2 players. Thus you get $10 + 2 \times 6 = 22$ points in total added to your account.

Every player can **choose** in every period **between six different conditions**:

- 0=Contribute in any case.
- 1=Contribute only if at least one other player contributes, too.
- 2=Contribute only if at least two other players contribute, too.
- 3=Contribute only if at least three other players contribute, too.
- 4=Contribute only if all four other players contribute, too.
- 5=Contribute in no case.

The computer selects the highest amount of players, which can contribute to the project, without violation the condition of any player. These players will then automatically contribute to the project. The other players will not contribute.

Example 1: 3 players choose condition "1" and the other two players choose condition "5". Then those 3 players, who chose condition "1" will contribute to the project.

Example 2: 3 players choose condition "3" and the other two players choose condition "5". Then no player will contribute to the project.

Payoff of all periods

After it was determined who contributes to the project in a given period, all players get the corresponding points added to their account.

Then a new period starts. After 20 periods there will be a questionnaire. After the experiment you will be called to receive your money. You will receive your **earnings for all periods** at a rate of 40 points=1€. The payment will be private and in cash.

Program structure

You obtained a printed example for the structure of the program, which you will use to submit your decision in every period. The screen is divided into three blocks.

The block on the upper left side contains a calculator. Here you can test conditions for you and the four other players. Once you select a condition for every player the computer will calculate the payoff you would obtain in this case.

In the upper right block you enter the condition that will be relevant for your payoff. Below there is a red button. When you push this button you submit your decision and leave the screen. Only when **all** players pushed the button the experiment continues. A clock on the upper right hints at the time in which your decision should be made. **If the time runs out this has <u>no</u> effect.**

From period two on the conditions of all players of all previous periods and your payoff in those periods will be displayed in the big block below. In the first period this block will be empty.

The texts in the green frames on the printed example of the program are comments that explain the print. They will not be displayed in the actual program.

6.3 Instructions for VCM with incomplete information

Instructions

Welcome to our experiment! Please read the instructions carefully. Do not talk to your neighbor from now on. Shut down your mobile phone and keep it turned off until the experiment ends. If you have any questions, raise your hands. We will come to you. All participants have got the same instructions.

In the experiment you will be divided in **groups of 5**. The experiment will last for **20 periods**. You will be grouped with the same four players in all periods. The experiment is entirely anonymous. No player will be informed whom he was grouped up with or what payoff any other player obtains.

Points are the currency in the experiment. In every period you start with 10 points. These points will by the end of the period either be added entirely to your private account, or will be invested entirely into a common project.

At the beginning of the first period every player will be assigned one **type**, which he will keep **for the entire game**.

With a chance of 20% you are type 1 and you do not benefit from the common project. In this case in each period your 10 points will be added to your private account if you do not invest them into the project. And 0 points will be added to your private account if you invest into the project. If any other players invest into the project does not influence your payoff in this case.

With a chance of 80% you are type 2 and you benefit from the common project. In this case in each period your 10 points will be added to your private account as well if you do not invest them into the project, but 6 points will be added to your private account if you invest into the project. Additionally you receive 6 points for every other player, who also invests into the project.

The types are drawn independently, especially different players may thus have different types. Every player gets displayed his type in every period. He does not get to know the types of the other players.

Example 1: You are type 2 and you invest you 10 points into the project and 2 other players invested into the project additionally. You will get for your investment and for the investment of the other 2 players 6 points each. Thus you will get $3 \times 6 = 18$ points in total added to your account.

Example 2: You are type 2 and you do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get additionally 6 points each for the investment of the other 2 players. Thus you get $10 + 2 \times 6 = 22$ points in total added to your account.

Example 3: You are type 1 and you do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get no additional points for the investment of the other 2 players. Thus you get 10 points in total added to your account.

Every player can choose in every period between two actions:

- You can invest your 10 points into the project.
- Or you can keep your 10 points for yourself.

All players decide simultaneously.

Payoff of all periods

After it was determined who contributes to the project in a given period, all players get the corresponding points added to their account.

Then a new period starts. After 20 periods there will be a questionnaire. After the experiment you will be called to receive your money. You will receive your **earnings for all periods** at a rate of 40 points=1€. The payment will be private and in cash. If you are type 1 you will receive 5€ additionally to compensate for your lower earning possibilities.

Program structure

You obtained a printed example for the structure of the program, which you will use to submit your decision in every period. The screen is divided into three blocks.

The block on the upper left side contains a calculator. Here you can test actions for you and the four other players. Once you select an action for every player the computer will calculate the payoff you would obtain in this case.

In the upper right block you enter the action that will be relevant for your payoff. Additionally in this block your type is displayed and whether you benefit from the project. Below there is a red button. When you push this button you submit your decision and leave the screen. Only when **all** players pushed the button the experiment continues. A clock on the upper right hints at the time in which your decision should be made. **If the time runs out this has no effect.**

From period two on the actions of all players of all previous periods and your payoff in those periods will be displayed in the big block below. In the first period this block will be empty.

The texts in the green frames on the printed example of the program are comments that explain the print. They will not be displayed in the actual program.

6.4 Instructions for CCM with incomplete information

Instructions

Welcome to our experiment! Please read the instructions carefully. Do not talk to your neighbor from now on. Shut down your mobile phone and keep it turned off until the experiment ends. If you have any questions, raise your hands. We will come to you. All participants have got the same instructions.

In the experiment you will be divided in **groups of 5**. The experiment will last for **20 periods**. You will be grouped with the same four players in all periods. The experiment is entirely anonymous. No player will be informed whom he was grouped up with or what payoff any other player obtains.

Points are the currency in the experiment. In every period you start with 10 points. These points will by the end of the period either be added entirely to your private account, or will be invested entirely into a common project.

At the beginning of the first period every player will be assigned one **type**, which he will keep **for the entire game**.

With a chance of 20% you are type 1 and you do not benefit from the common project. In this case in each period your 10 points will be added to your private account if you do not invest them into the project. And 0 points will be added to your private account if you invest into the project. If any other players invest into the project does not influence your payoff in this case.

With a chance of 80% you are type 2 and you benefit from the common project. In this case in each period your 10 points will be added to your private account as well if you do not invest them into the project, but 6 points will be added to your private account if you invest into the project. Additionally you receive 6 points for every other player, who also invests into the project.

The types are drawn independently, especially different players may thus have different types. Every player gets displayed his type in every period. He does not get to know the types of the other players.

Example 1: You are type 2 and you invest you 10 points into the project and 2 other players invested into the project additionally. You will get for your investment and for the investment of the other 2 players 6 points each. Thus you will get $3 \times 6 = 18$ points in total added to your account.

Example 2: You are type 2 and you do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get additionally 6 points each for the investment of the other 2 players. Thus you get $10 + 2 \times 6 = 22$ points in total added to your account.

Example 3: You are type 1 and you do not invest your 10 points into the project and 2 players invested into the project in total. Your will keep your 10 points and get no additional points for the investment of the other 2 players. Thus you get 10 points in total added to your account.

Every player can **choose** in every period **between six different conditions**:

- 0=Contribute in any case.
- 1=Contribute only if at least one other player contributes, too.
- 2=Contribute only if at least two other players contribute, too.

- 3=Contribute only if at least three other players contribute, too.
- 4=Contribute only if all four other players contribute, too.
- 5=Contribute in no case.

The computer selects the highest amount of players, which can contribute to the project, without violation the condition of any player. These players will then automatically contribute to the project. The other players will not contribute.

Example 1: 3 players choose condition "1" and the other two players choose condition "5". Then those 3 players, who chose condition "1" will contribute to the project.

Example 2: 3 players choose condition "3" and the other two players choose condition "5". Then no player will contribute to the project.

Payoff of all periods

After it was determined who contributes to the project in a given period, all players get the corresponding points added to their account.

Then a new period starts. After 20 periods there will be a questionnaire. After the experiment you will be called to receive your money. You will receive your **earnings for all periods** at a rate of 40 points=1€. The payment will be private and in cash. If you are type 1 you will receive 5€ additionally to compensate for your lower earning possibilities.

Program structure

You obtained a printed example for the structure of the program, which you will use to submit your decision in every period. The screen is divided into three blocks.

The block on the upper left side contains a calculator. Here you can test conditions for you and the four other players. Once you select a condition for every player the computer will calculate the payoff you would obtain in this case.

In the upper right block you enter the condition that will be relevant for your payoff. Additionally in this block your type is displayed and whether you benefit from the project.

Below there is a red button. When you push this button you submit your decision and leave the screen. Only when **all** players pushed the button the experiment continues. A clock on the upper right hints at the time in which your decision should be made. **If the time runs out this has <u>no</u> effect.**

From period two on the conditions of all players of all previous periods and your payoff in those periods will be displayed in the big block below. In the first period this block will be empty.

The texts in the green frames on the printed example of the program are comments that explain the print. They will not be displayed in the actual program.

Appendix B

In addition to instructions subjects had to fill out a slide of comprehension questions. A translation of the German original is given exemplary for the case of the CCM and incomplete information:

Comprehension questions - Experiment PGCCM

You are asked to complete two test questions to check whether you understood the instructions completely.

Choose in the following test question 1 a condition for each player. Choose at least **three different** conditions:

Your condition (player 1): ___

Condition player 2: ___

Condition player 3: ___

Condition player 4: ___

Condition player 5: ___

Underline those players, who would contribute to the project in this case:

Player 1 Player 2 Player 3 Player 4 Player 5

What payoff would you obtain in this period if you are of type 2? __________

Choose also in the following test question 2 a condition for each player. Choose at least **three different** conditions, such that the number of players, who contribute to the project, differs in test question 1 and 2:

Your condition (player 1): ____

Condition player 2: ____

Condition player 3: ____

Condition player 4: ____

Condition player 5: ____

Underline those players, who would contribute to the project in this case:

Player 1   Player 2   Player 3   Player 4   Player 5

What payoff would you obtain in this period if you are of type 1? ___________

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