

First Come, Best Served?

Real-Time Provision of Threshold Public Goods

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Preliminary Version

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Abstract

Climate change negotiations can be modeled as sequential contributions to a threshold public good in which the order of contributions arises endogenously. In an experiment we explicitly account for the endogeneity of the contribution order. A comparison of cooperation patterns to the case of an exogenous sequential provision of threshold public goods yields new evidence on what factors drive behavior in cooperation problems. We elicit the importance of leadership for the successful provision of the public good and the effects of free riding on behavior in later positions. Our data also suggests that a free allocation of contribution positions does not improve cooperation rates and payoffs.

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1 Introduction

Both the creation of international treaties as well as the adherence to them can be interpreted as public goods. Parties have to decide on how much to contribute to the public good as well as when they do so. The timing of announcements has potentially large effects on cooperation possibilities. Early announcements can induce other parties to follow suit when the announced contribution is high, but they also might harm cooperation when they are judged inappropriate by the other parties. In the context of climate change it could be seen that after the United States pulled out of the negotiations in 2001, the Kyoto protocol was significantly watered down (Since the adoption of the Kyoto protocol in 1997 global carbon-dioxide emissions have risen by 25%). However, the aim to stop global warming at 2°C will require considerable emission cuts of most industrialized and developing countries.

We analyze negotiation patterns and cooperation rates using a laboratory experiment. In particular, we model the negotiation process as the provision of a threshold public good to which agents are free to make irrevocable contributions at any point in time. The order in which agents contribute is thus naturally given by the timing of their announcements. This for example relates to an ongoing negotiation. To make a pledge in the negotiation process, politicians have to fight for domestic support, which costs political capital no matter whether the negotiations later turn out to be a success or not. The higher the pledge that is to be made, the higher the political costs. Only when the negotiations succeed can political benefits be reaped.

The explicit modeling of the endogeneity of the commitment sequence allows us to analyze negotiations in a stylized but more realistic setup. We are particularly interested in the way in which the success of the project depends on the contributions of the first player. The contribution of the first party arrests the attention of the other parties and might be able to encourage them to contribute highly. Alternatively, a small contribution, as for example the one announced by the United States in 2001, can lead to a failure of negotiations. To better understand behavioral patterns when the contribution order is endogenous, we also contrast our results to a treatment where the contribution order is exogenously fixed. We will focus in particular on the efficiency and allocative fairness of both treatments.

Apart from the pure negotiation framework, our setup corresponds to real investments that are made domestically and sequentially when the returns to overall investments are similar to those from a threshold public good as it is the case with thresholds in the global climate. Early investments into emission reductions may be used either to encourage other countries, or, in the case of low investments, credibly signal to other countries that they would have to bear the larger burden of abatement. This is especially true if the citizenry believes that investments will not be put again on the political agenda in the near future. We believe this to be an appropriate description of reality since investments that are made explicitly conditional on other countries' investments are rarely observed.¹

The next section reviews the related literature. Hypotheses on likely behavior are formulated in section three. Section four describes the experimental design in detail. Experimental results are discussed in section five. Section six draws conclusions from the experiment and section seven discusses avenues for future research.

¹The offer of the European Union to increase emission abatements from 20% to 30% conditional on other countries' commitments is a notable exception.

2 Related Literature

A key question in sequential social dilemma situations is whether leading parties can induce others to restrain from taking selfish actions and to contribute to achieve a socially efficient outcome. For linear payoff structures, this pattern is well documented (Moxnes & van der Heijden 2003, Potters et al. 2005, Güth et al. 2007, Rivas & Sutter 2009). Rivas & Sutter (2009) additionally contrast an exogenous assignment of leaders to endogenously arising leadership and show that players who select themselves into the first position contribute more than players who were assigned into the same position. Thus, overall contributions to the linear public good are higher when the order of contributions arises endogenously. Clearly, announcing contributions early in a linear public good framework is only beneficial when the aim is to induce cooperation with high contributions. Since players in later positions mimic contributions only in part, early contributions typically go along with lower earnings. Players thus prefer later positions (Arbak & Villeval 2007, Güth et al. 2007, Rivas & Sutter 2009).

For payoff structures that resemble threshold public goods, even though they are present in many social dilemma situations, cooperation patterns remain largely unexplored. When the payoff of a public good inhibits a threshold and full participation is not required, higher contributions of one player allow for lower contributions of another and vice versa. With sequential contributions, early positions uniquely allow for free riding. The efficiency of an endogenously arising order of contributions in a threshold public good will thus depend on (i) whether players move early in order to encourage other players to contribute fairly or whether they try to exploit later players with low contributions and (ii) how later players respond to contributions of early movers.

An early study examining behavior in endogenous sequential threshold public goods problems is provided by Dorsey (1992). He allows for multiple and continuous contributions and shows that players implicitly condition their contributions on other players' contributions by raising contributions incrementally when others do so as well. In contrast to Dorsey (1992) we focus on single contributions. In doing so we exclude the possibility to condition contributions and allow early commitments to low contributions, which generates a theoretical first-mover advantage.

Goren et al. (2003) and McEvoy (2010) focus on single, all-or-nothing contributions. The former paper studies heterogeneously endowed players and indicates that subjects with a low endowment contribute their full endowment early. The latter analyzes all-or-nothing contributions of homogeneous players and shows that players in early positions only free ride when the relative payoff of free riders is high. In contrast to these studies we allow for the possibility of partial free riding by allowing continuous contributions in each position. We also focus on a better understanding of the driving forces of behavior in the endogenous move setup by contrasting our results to the benchmark of an exogenous order of contributions.

There is yet no theoretical result for behavior with multiple players in a threshold public good when players can freely decide on both their share of contributions and positions. For a threshold public good that can be provided by one person alone, Bliss & Nalebuff (1984) and Bilodeau & Slivinski (1996) show, that if the payoff from the public good is dependent on the time when it is produced, waiting will be used as an allocation device to decide on who should provide the public good. Waiting is used to signal one's cost of provision of the public good which will eventually be provided by the party with the lowest cost. However, due to complexity, no similar studies exist for the case of public goods that require contributions by multiple players.

Thus, this paper provides valuable insights into behavior in the described setup. To

guide our analysis, we provide a simple model with selfish and homogenous players in the appendix.

3 Theoretical Predictions and Hypotheses

In sequential threshold public good problems the leading positions do not only offer the opportunity to persuade others to contribute to the common good. They also bring the theoretical chance to commit to free ride and thus leave the provision of the public good to the other parties. Indeed, strategies that prescribe lower contributions at early positions form the only subgame perfect Nash equilibrium with exogenously ordered contributions and the only trembling-hand perfect Nash equilibrium with endogenously ordered contributions.² It has also been shown experimentally by Coats et al. (2009), that exogenously appointed early movers exploit their positions to some degree. We expect to see the same when we endogenize the order of contributions.

Hypothesis 1. *Early movers will try to contribute less to the public good than others.*

Since strategies in the trembling-hand perfect Nash equilibrium prescribe lower contributions for early positions, they also stipulate early moves for the player. Our second hypothesis is thus a direct consequence of our first hypothesis.

Hypothesis 2. *Players will try to move early.*

The players' payoffs are increasing in the probability of public good provision. Take players that are concerned not only about their own material payoff but also about social welfare and reciprocity as specified in Charness & Rabin (2002). Then, when the move order is endogenous, players can increase the probability of public good provision not only by their contributions but also by their move order. Assume, that two of four players have already moved and at least one of them tried to free ride on the later players. For the sake of the argument we further assume that one of the remaining players is strongly reciprocal such that free riding players have zero weight in the social welfare part of her utility function. The other player knows that and is not reciprocal himself. By moving before the strongly reciprocal player, she can increase the probability of public good provision because a punishment from the reciprocal player by contributing zero would now hurt one more player and is thus less likely. In contrast, when the move order is exogenously fixed, this channel of self-organization is not present. We thus form the following hypothesis:

Hypothesis 3. *The endogenous mechanism is more efficient than the exogenous mechanism.*

The experimental design is described in the following section.

4 Experimental Design

The experiment took place in the laboratory of the University of Bonn in April 2010. It was conducted using z-Tree (Fischbacher 2007), recruitment took place using ORSEE (Greiner 2004). Two treatments were performed in a total of six sessions: endogenous order of contributions to a threshold public good using the real-time protocol (which we will refer to as END) and an exogenous order of contributions to the same threshold public good (which we will refer to as EX). Both treatments consisted of 10 rounds with

²Please refer to the appendix for a theoretical prediction of behavior in this setup.

stranger matching within two matching groups of 12 subjects each per session. In total, 144 subjects participated in the experiment. Average earnings in this experiment were 6.30 Euro. Efficient public good provision in each round would have generated average earnings of 8 Euro.³

4.1 Basic Problem and Payoffs

Parameters were chosen to be comparable to Coats et al. (2009) and Coats & Neilson (2005) but were scaled up to allow a more differentiated choice of contributions by the subjects. Subjects were provided with an endowment of 50 tokens. They were partitioned in groups of 4 and could decide how much of their endowment they want to contribute to a public project. If the contributions to the public project reached or exceeded the threshold of 120 tokens then the project would pay 60 tokens to each subject irrespective of the individual contributions. A subject's payoff would thus be

$$\pi_i = (50 - c_i) + \begin{cases} 60 & \text{if } \sum_{j=1}^4 c_j \geq 120 \\ 0 & \text{otherwise} \end{cases}$$

where π_i denotes individual earnings in a given period and c_i denotes individual contributions to the public good. One token was worth one Eurocent. Contribution announcements could not be revised. In addition, if the threshold of 120 tokens was not reached, contributions were not refunded. This form of commitment required by our setup is analogue to costly and irreversible investments or announcements that are very costly to change.

4.2 Endogenous Treatment

The endogenous treatment (END) allowed subjects to freely decide on when to contribute. Announcements immediately appeared on the screen of every group member. For an impression of the interface, please refer to the instructions in the appendix.

Subjects had 60 seconds to enter their contribution into the screen. To avoid time pressure, they were given a time extension of 20 seconds if contributions were made after 40 seconds had passed. The remaining time in a specific period was not reduced even if a group had finished before the 60 seconds passed. In addition, subjects were given ten seconds to get ready at the beginning of each period. To ensure that the order in which subjects would announce their contributions was strictly sequential we imposed a two seconds waiting time after an announcement was made. During this time, no followup contributions could be announced. When no announcement was made at all by a player this was evaluated as a contribution of zero tokens. We made sure that subjects understood the setup by asking control questions and implementing two test periods. In the test periods subjects only interacted with three computer players who were announcing contributions in the form of a prespecified text at random points in time. Subjects could themselves announce a hypothetical choice.

4.3 Exogenous Treatment

In the exogenous treatment (EX), subjects were randomly assigned a position which was fixed over all periods. To ensure that the treatments were comparable, every subject had

³The experiment continued for 10 rounds with the opposite treatment and also included post tests. The analysis performed herein only refers to the first 10 rounds.

15 seconds to make her decision at the prespecified position. Effectively, every group again had 60 seconds to decide on contributions, so time pressure was comparable. When no decision was made by a subject within the 15 seconds assigned to her, this was again evaluated as a zero contribution.

5 Experimental Results

In this section we present results on behavior when cooperation has to be achieved in real-time with an endogenous order of contributions. Throughout our analysis, we will take the setup with an exogenously given order as a benchmark.

5.1 General Behavior

The public good is successfully provided in 56% of all possible cases in the endogenous treatment. Average contributions equal 22.2 tokens and show no trend over the different positions (see Table 1). The fact that early contributions are below 30 lends first support to Hypothesis 1.⁴ Contributions that purposefully lead to the impossibility of public good

Table 1: Average contributions by position

Position	1	2	3	4
END	22.47	24.28	21.05	20.80
EX	23.07	19.92	20.59	21.18

provision, something that we will henceforth call folding, keep average contributions in later positions below 30. If we only look at contributions that permit the provision of the public good, we can see a clearly increasing trend in contributions (Wilcoxon signed-rank test for all pairwise comparisons, $p=0.03$)⁵ depicted in Table 2. Taking a closer look at

Table 2: Average contributions by position when the public good can still be provided, without folding

Position	1	2	3	4
END	22.47	26.27	28.38	36.19
EX	23.07	22.69	30.23	35.40

the contributions in the first position with Figure 1, it shows we can categorize first mover contributions into four categories:

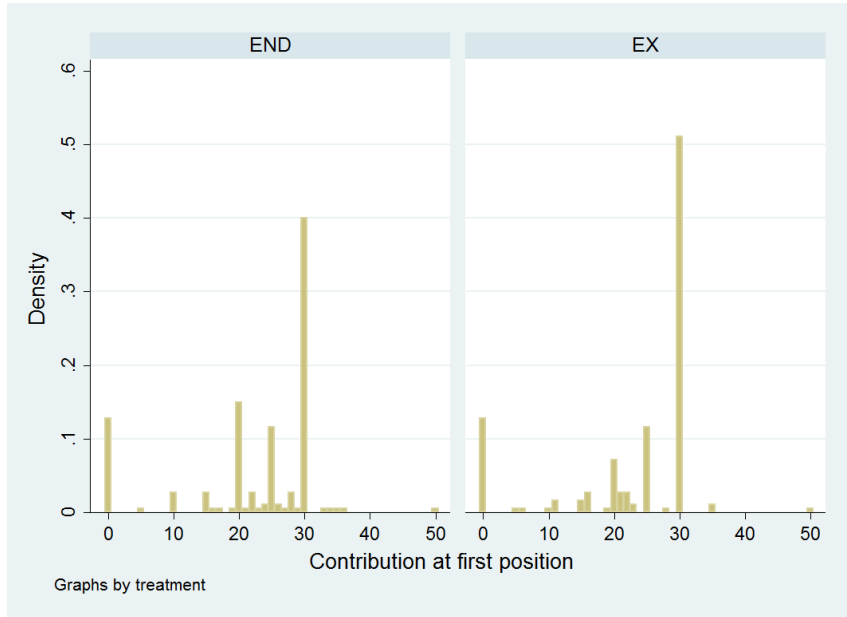
42.8% of all contributions in the first position aim at providing an equal share of the public good, i.e. 30 token or more. 21.6% of all contributions lie strictly between 20 and 30 tokens and are centered at 25 tokens. We label them as mild freeriders. A higher degree of free riding is attempted with 22.8% of the contributions, the overwhelming majority of which is represented by contributions of 20 tokens. Finally, the strongest degree of free riding, with zero contributions, is visible in 12.8% of all contributions. We can conclude that, in contrast to linear public goods, we see free riding in early positions. In particular, the last player is forced to contribute 36.2 tokens on average if he wants the public good to be provided. We thus find support for Hypothesis 1.

Result 1. *Early movers try to contribute less to the public good than others.*

⁴We will henceforth define contributions of 30 tokens and above as fair.

⁵All tests are performed on the matching group level. The stated p-values are two-tailed.

Figure 1: Distribution of contributions in the first position



Since early positions prominently allow for free riding we also hypothesized that they should be favored by the players. Indeed we find that, when faced with the decision situation, subjects favor the first position. The first contribution is made in the first two seconds in 81 percent of all periods and in the first ten seconds in 96.7 percent of all periods. The average time that passed before a position was taken increased over the positions (Later positions took an average of 10.5 seconds before they were taken). This is even the case when only histories with no free riding are considered, as reported by Table 3. In principle, these histories still allow for free riding of later positions and should thus be favorable still. All differences in the time passed up to the third position are pairwise statistically significant (Wilcoxon signed-rank test, $p < 0.05$). If we classify

Table 3: Average time passed after the previous contribution when all contributions have been fair

Position	1	2	3	4
time passed (in sec)	2.5	6.7	9.5	8.9

players according to their preferences for a specific position we find that about 54% of all subjects display a preference for the first position, preferences over the remaining three positions are divided at 7%, 5.5% and 9.8% for positions 2, 3 and 4 respectively. 23% of all subjects do not display a clear preference for a specific position.⁶ The results of both evaluation methods are thus in favor of Hypothesis 2 even if we would also expect later positions to be taken quickly when no free riding occurred.

Result 2. *The majority of subjects prefer the first position.*

⁶We elicit preferences for positions by counting the first attempt to contribute, whether it was successful or not. An attempt to contribute is recorded as failed when it was made within two seconds after the original contribution, as described in the experimental design. If there was a unique position that the subject favored most and the subject wanted to contribute at this position four times or more often the subject was categorized as preferring that specific position. We also asked subjects for their preferred positions in the postexperimental questionnaire and used their answers as a validity check for our measure of the preferred positions.

In line with the theory, this suggests that the underlying features of the negotiation problem we study does not exhibit a high value of waiting. In particular, subjects in general do not wait for others to contribute early such that they could base their contribution decision on the behavior of the other group members.

5.2 Efficiency

Contrary to linear public goods, we find that the free allocation of contribution positions does not help to foster cooperation. In particular, groups were only able to provide the public good successfully in 56.1% of the cases, whereas, when the order of contributions was fixed, the public good was provided in 59.4% of the cases. The observed difference is not statistically significant (robust rank order test, $\hat{U} = -0.197$, $p > 0.2$). The efficiency of the mechanisms is directly reflected by the earnings of the players. The average earnings achieved by the groups using the different mechanisms are also not statistically significant (robust rank order test, $\hat{U} = 0.737$, $p > 0.2$) with earnings in END being 61.5 tokens while subjects in EX earned 64.5 tokens on average (see Table 4).

Thus, we find no support for Hypothesis 3.

Table 4: Efficiency in the treatments

	Endogenous	Exogenous
Success rates	56.1%	59.4%
Earnings (in tokens)	61.5	64.5

We pointed out earlier that the performance of the mechanisms depends on two aspects. First, the contributions made in the first position and thus also on who takes the first position. And second, how later positions react to behavior of the first position. We will consider both in turn.

5.2.1 Behavior in Early Positions

Looking at the contributions in the leading position, it can be seen from Figure 1 that they were similar. The average contributions in END of 22.5 tokens is not statistically different from the average contributions of 23.07 in EX (robust rank order test, $\hat{U} = 0.141$, $p > 0.2$).

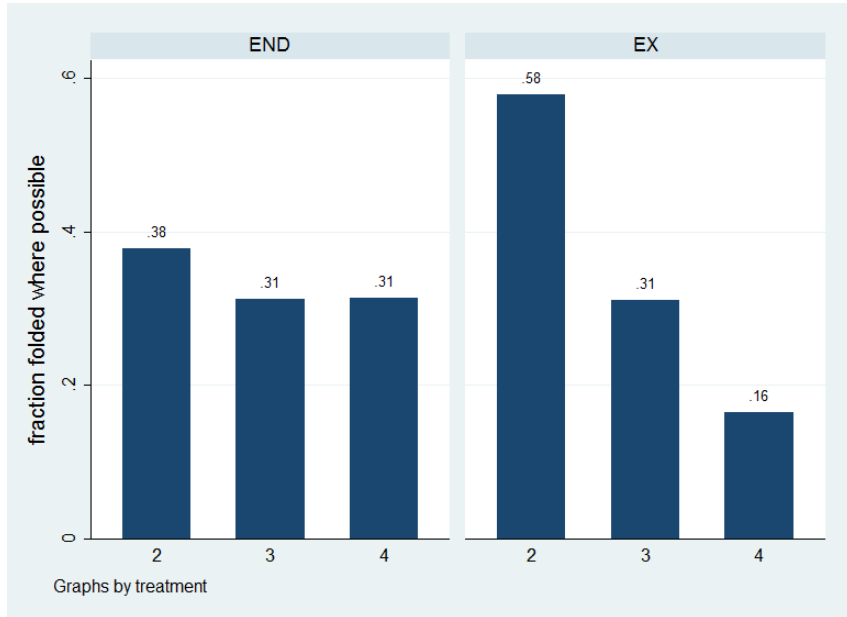
Again in contrast to linear public goods, a free allocation of positions does not lead to higher contributions in the first position. From our previous analysis of preferences for different positions, we suppose preliminarily that this stems from players deliberately choosing the first position to free ride and not so much from the same types of players behaving more selfish.

5.2.2 Behavior in Later Positions

The reaction to contributions in previous positions differs among the treatments. Figure 2 displays the fraction of folds in situations where folding was possible and the history contained unfair contributions.⁷ If the move order is endogenous, only 38% of players in the second position decide to fold when they have seen an unfair contribution in the first

⁷If situations are unfair, the total amount of contributions from previous positions are not significantly different over the treatments (robust rank order test, $p > 0.2$). For the second position, they are 16.5 tokens and 15.0 tokens, the third position saw a total of 22.7 tokens and 22.3 tokens and the fourth position faced total contributions of 26.2 tokens and 26.6 tokens in END and EX, respectively.

Figure 2: Folding behavior in different positions when history contained unfair contributions



position. In the benchmark treatment, 58% decide to fold in similar situations. However, the flipside of the coin is that the unfair situations prevail longer in END since they remain unfolded. Consequently a total of 31% of players in the fourth position decide to fold, whereas in EX, the number corresponds to 16%.

Tests of equality of proportions on folding behavior show that the difference is significant at position 4 ($z = 2.36, p = 0.0185$) and weakly significant at position 2 ($z = -1.74, p = 0.082$). Obviously, folding in later positions is detrimental to the efficiency of the mechanism, since more contributions are then forfeit. As a result, the average amount of contributions lost when the public good is not provided is 47.4 tokens in END, but significantly lower in EX at 33.1 tokens (robust rank order test, $\hat{U} = 2.502, p < 0.05$). To explain the comparatively low amount of folding at the early positions in END, consider a situation in which the first position provided less than its fair share. A player that feels uncomfortable with the given history has three options. She can either contribute, fold, or wait. Note, that both folding and waiting guarantee a minimal payoff given by the endowment. However, waiting additionally comprises an option value for higher payoffs if other players continue to contribute. Waiting is thus preferable to folding from an individual perspective. Nevertheless, it also produces a negative externality on the other players that are, due to the inaction, not informed about the player's discontent. These costs on the other players, finally, are not considered in their full extent, neither in the decision to wait, nor in the decision to fold.

Additional evidence that waiting is preferred to folding is presented in Table 5. In situations where previous positions contributed less than the fair amount, more time passed when the eventual decision made at this position was to fold. I.e. folding was not done impulsively but rather only when longer periods of waiting did not bring forth a player that is willing to contribute. Naturally, this effect is not present at the fourth position.

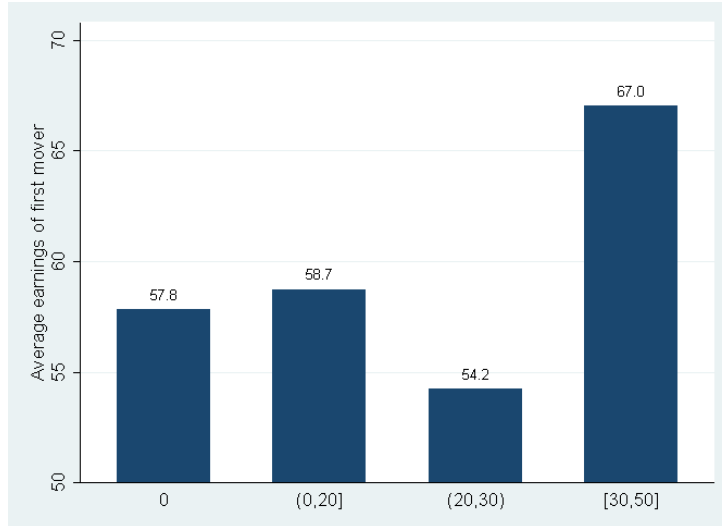
Both features, contributions in the first position that are not higher and a more observant behavior when it comes to folding, lead to the fact that the self-organization of groups in END is not more efficient than with exogenously imposed positions. We thus

⁸Observations where folding is performed by waiting either individually or collectively are excluded from the table.

Table 5: Average time passed after the previous contribution if at least one previous contribution was unfair, but the public good could still be provided⁸

fold	position		
	2	3	4
no	11.4	11.5	12.7
yes	24.5	17.8	8.6

Figure 3: Average earnings of the first mover depending on contributions



find no support for Hypothesis 3.

Result 3. *The endogenous mechanism is not able to provide the public good more efficiently than with exogenously given positions.*

5.3 Profits when Free Riding

Especially in negotiation situations it is important to know whether a high concession of a first mover can induce other parties to follow the lead and thus is beneficial for the first mover from a payoff maximizing perspective. We cluster first mover contributions with their degree of fairness and depict average payoff conditioned on the fairness of the contribution. In climate change negotiations in particular there is a strong notion that going first with a high contribution does not pay off. In our experiment, we find the opposite. If parties can freely decide on when to contribute, a higher contribution in the first position achieves larger expected payoffs (67.0 tokens for a contribution that exceeds 30 tokens vs. 58.7 tokens for a contribution below 20 tokens, compare Figure 3)⁹. The difference is statistically significant (Wilcoxon signed-rank test, $p = 0.046$)¹⁰. By virtue of high correlations between early and later movers' contributions, maximizing expected payoffs thus requires a fair contribution in the END treatment when moving first.

Table 6 also gives an overview of average profits from attempted free riding for later positions. To ensure comparability, it only includes situations in which exclusively fair contributions have been observed so far. It can be seen that contributions below 30 seem to decrease expected public good provision as much as to diminish expected profits also

⁹Note that with everybody contributing 30, a payoff of 80 would have been possible

¹⁰To obtain observations for each free riding category on the matching group level, we compare payoffs with contributions of 30 and above with payoffs when contributions are below 30.

Table 6: Average payoff depending on contribution, given fair history

contribution	position		
	1	2	3
0	57.8	50.0	50.0
(0,20]	58.7	68.8	80.3
(20,30)	54.2	60.5	80.5
[30, 50]	67.0	73.7	80.0

in the second position. This is no longer the case for the third position.¹¹ The fourth player will take the two fair contributions into account when she considers folding and thus becomes more likely to provide the remaining contribution. However, folding in the fourth position still occurs frequently enough such that free riding does not increase expected profits significantly. We thus can conclude the following result.

Result 4. *Contributing less than the fair amount in position one in END reduces expected payoffs.*

Contrary to free riding, early movers can also try to induce fair allocations by contributing their fair share to the public good, thereby trying to set a fairness norm. Theoretically, this would make them prone to exploitation by later players, who would reduce their contributions accordingly. However, we find that this happens rarely. If first movers start with contributions below 30 tokens, 54.3% of second movers decide to free ride as well, whereas, if first movers start with contributions equal to or exceeding 30 tokens, the corresponding number is significantly reduced to 31.9% (test of equality of proportions, $z = 2.87$, $p = 0.0042$).

Result 5. *In END, early movers can induce fair allocations by contributing fairly themselves.*

5.4 Impact of Later Positions

It could be conjectured from the results mentioned above, that certain contribution histories include early contributions that make a failure of the project likely. Later positions still may contribute to the public good but public good provision fails eventually. It is thus natural to ask how later positions may influence the success of public good provision if free riding has already taken place. To account for the different degrees of free riding, we perform a regression analysis of payoffs on individual contributions. If the effect on success rates is sufficiently strong, we will also see an effect on individual earnings. Table 7 displays the results of the random effects regression. For the analysis, only non-final positions where public good provision was still feasible but where free riding has been observed are taken into account. We control for different degrees of free riding by including the variables position¹² and ADL into the regression. ADL describes the amount of free riding. More precisely, it entails the average amount of contributions exceeding 30, that would be required from the current and succeeding positions to successfully provide the public good. We observe that higher contributions go along with lower expected earnings, but when contributions are sufficiently high, higher contributions actually increase

¹¹The effects are insignificant, however, for both positions (Wilcoxon signed-rank test, $p > 0.15$).

¹²Public good provision becomes more likely, the longer its feasibility was upheld and thus the more contributions would be lost in case of folding. This effect is reflected by the positive coefficient of the position. Higher earnings can be expected from the fact alone that later movers are less likely to fold.

expected earnings. Then, the increase in expected public good provision offsets the losses incurred by the contribution. However, previous free riding not only decreases expected profits in general but also decreases the positive effects of one’s own contribution, as can be seen by the interaction effect between ADL and contribution.

We can conclude from our data, that high contributions as a reaction to previous free riding help expected public good provision enough to make them individually rational for mild degrees of free riding.

Table 7: Random effects GLS regression results ¹³

Earnings	Coefficient	(Std. Err.)
Contribution	-0.966*	(0.466)
Contribution ²	0.054**	(0.015)
ADL*Contribution	-0.109**	(0.024)
ADL	-0.476	(0.301)
Position	6.444*	(2.704)
Intercept	39.069**	(7.475)
N		215
Wald $\chi^2_{(5)}$		75.210**

6 Summary

Our experiment depicts, in a stylized way, negotiation situations where the cooperative outcome requires a fixed amount of resources. Both theoretically and experimentally, we have shown that moving early is favored in this case and free riding occurs in early positions. However, free riding does not seem to be an equilibrium phenomenon from a payoff maximizing perspective. Even though individual contributions should increase with higher positions due to the payoff structure, later movers often deviate from their best response and give up on public good provision.

Our results also suggest that the indeterminacy of the endogenous move structure when to make a concession does not increase chances for successful completion of a threshold public good provision. The endogenous move structure suffers particularly from the lacking necessity to decide on folding right after dissatisfactory contributions have been made. Waiting is individually rational but generates negative external effects on the other players. Consequently, more contributions to the public good will have been made when a player eventually decides to give up on the provision of the public good. This is in stark contrast to the case of linear public goods where a move order chosen by self-organization has been shown to increase efficiency. The threshold in the payoff structure, which allows free riding in the first position, seems to suppress this effect.

We also find that if positions are freely allocated, the party contributing first should choose a fair contribution since this increases prospects for successful public good provision considerably in our data and thus maximizes own expected payoffs. Also in later positions, contributing fairly affects folding behavior of later players to a degree that makes it weakly preferable to lower contributions. Early fair contributions also rather induce other players to behave fairly.

¹³Note:**(*) denotes 1% (5%) significance. Bootstrapped standard errors are given in parentheses.

7 Further Research

This paper has shown the underlying motives which shape behavior in threshold public goods problems if the order of contributions arises endogenously. To the extent that these particular underlying incentives might interact with institutions, a reconsideration of the effect of institutions is warranted. For example, we assumed that states negotiate publicly and thus have to bear all political costs of their compromises. However, states also have the option to negotiate in private which might be conducive to cooperation (Barrett 2003). In the case of negotiation failure, states would then not have to bear the political costs of their compromises since they are only made public in the case of successful negotiation. Such a situation can be simulated by a refund rule. Contributions are then refunded if the threshold of the public good is not achieved. While the desirability of transparency in negotiations remains debatable, previous research by Coats et al. (2009) has found no effect of a refund rule on efficiency for an exogenously given order of players. With our experiment we also laid the foundation for a reassessment in the endogenous framework.

For this paper we have assumed homogeneity of the players in the game.¹⁴ Usually, players differ with regard to their endowment (as could be interpreted as economic strength or as a difference in marginal abatement costs) or their payoff from the public good (as could be interpreted as different vulnerability to the underlying problem). Naturally, an assessment of how heterogeneity alters incentives in the endogenous framework is also warranted. A framework with observable heterogeneity would allow us to assess whether an early move of some players is more conducive to public good provision and how the tendency to accommodate to free riders differs among types.

¹⁴Heterogeneity among the players was only present implicitly by differing risk aversion and social preferences.

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A Theoretical Equilibrium with Endogenously Ordered Contributions

A.1 Equilibrium with Selfish Players

Take $N \in \mathbb{N}$ players, each endowed with e tokens. The public good requires $M > e$ tokens to be successfully provided and, if provided, pays out g tokens with $Ng > M$ such that the provision of the public good is socially efficient. Without loss of generality, assume $g > e$. Irrevocable contributions can be made anywhere on the support T of the time dimension where $T \subset \mathbb{N}$. Define p^{t-1} as a row vector containing $t - 1$ dummy variables indicating the time periods at which contributions took place. Likewise, c^{t-1} is a column vector of length $t - 1$ containing the history of amounts contributed.¹⁵ Let then $d_{it}(c^{t-1}, p^{t-1}) \in \{0, 1\}$ indicate whether player i likes to announce contributions at time t given the observed history. To focus on strictly sequential contributions, if $\sum_i d_{it} > 1$ one player is chosen randomly and her contribution is implemented. Let $c_{it}(c^{t-1})$ denote the desired contribution of player i at time t . Then, $c_t = c_{it}$ where i is equal to a randomly selected i where $d_{it} = 1$. The strategy of a player i assigns every history a pair of (d_{it}, c_{it}) . For the sake of simplicity we define $c_{it}(c^{t-1}) = 0$ if $d_{it} = 0$ and let $d_{it} = 1$ if the player's strategy prescribes a specific contribution. Note that $m_t(c^{t-1}, p^{t-1}) = M - p^{t-1}c^{t-1} - (N - p^{t-1}\iota - 1)e$ is the minimal amount of contributions required by the player moving at time t to make provision of the public good still feasible.

We will derive the trembling-hand perfect Nash equilibrium¹⁶ with contributions increasing monotonously in the position. For payoff maximizing players

$$c_{it}(c^{t-1}, p^{t-1}) = \begin{cases} m_t(c^{t-1}, p^{t-1}) & \text{if } p^{t-1}\iota = N - 1 \text{ and } m_t(c^{t-1}, p^{t-1}) \leq e \\ 0 & \text{if } p^{t-1}\iota = N - 1 \text{ and } m_t(c^{t-1}, p^{t-1}) > e \end{cases}$$

strictly¹⁷ dominates strategies prescribing other contributions. I.e., the last undecided player should contribute the amount necessary to provide the public good, if this is still possible. This follows directly from $g > e$. Given that all players follow this strategy, one can also derive that

$$c_{it}(c^{t-1}, p^{t-1}) = \begin{cases} m_t(c^{t-1}, p^{t-1}) & \text{if } m_t(c^{t-1}, p^{t-1}) \leq e \\ 0 & \text{otherwise} \end{cases}$$

strictly dominates strategies prescribing other contributions at earlier positions. Contributions given by this rule prescribe to contribute at every time just as much to the public good as is required to make the later moving players still capable of providing the public good. If the strategy would prescribe higher contributions at time t , the directly subsequent player would reduce her contribution. Lower contributions at time t would hinder public good provision. Note that every players' strategy has to specify contributions for each possible position. We can conclude that, for a given history and a given position,

¹⁵Note that zero contributions are permitted such that a specific entry c_t could be zero whether or not the corresponding entry p_t is zero or one. Thus, the vector p^{t-1} is needed to distinguish zero contributions from no contributions.

¹⁶Other Nash equilibria also exist but feature non-payoff maximizing actions at nodes of the game that are never reached. By allowing for small mistakes of the other players, all nodes are reached with positive probability. Thus, these equilibria are ruled out.

¹⁷The strategies of the other players could also be such that $m_t(c^{t-1}, p^{t-1}) \leq e$ should never be achieved. However, allowing for mistakes of the other players still requires contributions to be chosen in the payoff maximizing way specified above.

players would always choose to contribute $m_t(c^{t-1}, p^{t-1})$. Since this strategy generates weakly higher payoffs for earlier positions, players cannot gain by deviating from

$$d_{it}(c^{t-1}, p^{t-1}) = \begin{cases} 1 & \text{if } m_t(c^{t-1}, p^{t-1}) \leq e \\ 0 & \text{otherwise.} \end{cases}$$

That is, as long as public good provision is still feasible players try to contribute as soon as possible. Note, that it does not matter whether players want to contribute at a specific position when the public good cannot be provided anymore and optimal contributions thus are zero. For convenience we then set $d_{it}(c^{t-1}, p^{t-1}) = 0$.

A.2 Instructions for End

In the following we provide the instructions for the END treatment. The instructions for EX were changed appropriately and are available upon request.

General Explanations for the Participants

You are now taking part in an economic science experiment. If you read the following explanations carefully, you can earn a significant amount of money, depending on the decisions you make. It is therefore very important that you pay attention to the following explanations.

During the experiment, you will not be allowed to communicate with anyone. Should you have any questions, please direct them directly to us. Not abiding by this rule will lead to exclusion from the experiment and from any payments.

In this experiment, we calculate in tokens rather than in euro. Your entire income will therefore initially be calculated in tokens. Your total income in tokens will consist of the sum of your earnings in all parts of the experiment. The total sum of your earnings will be calculated in euro and paid to you anonymously at the end of the experiment according to the exchange rate:

$$1 \text{ Token} = 1 \text{ Eurocent.}$$

The experiment will consist of several parts. All parts of the experiment are completely independent from each other. You will be matched with new participants in each part of the experiment. Similarly your earnings are not dependent on your decisions in a previous part. Your decisions are strictly anonymous, and you will never learn to which participants you were matched. In the same vein we will analyze your decisions anonymously and won't connect them with your identity.

On the following pages we will describe the exact procedure of the first part. Following that there will be additional parts, which we will explain as we go along.

Informations Regarding Part 1 of the Experiment

This part of the experiment will consist of 10 periods. You will be matched with new participants in each period. Your earnings in this part of the experiment are determined by the sum of your earnings in all periods.

The Decision Situation

Before we will explain the exact procedure of the experiment, we will first explain to you the basic decision situation you and the other participants will face.

The participants will be matched in groups of 4 persons each. Thus, there will be three other members in your group. Each participant will be assigned a certain color for identification purposes which will have no further meaning and may change in the course of the experiment.

Each participant will have a private account which will have a starting balance of 50 tokens (the so-called endowment). Your group will thus have a total amount of 200 tokens on private accounts. In addition to the private accounts, there will also be a group project.

Each participant will have to decide how many of the 50 tokens she wants to contribute to the group project. This has to be a natural number between zero and 50. These tokens will be deducted from her private account.

The contribution decisions will be made sequentially. As soon as a member of your group will make a decision about her own contribution to the group project, all other members of the group will be informed about this contribution. As soon as a participant has made a contribution decision, this decision cannot be changed.

Calculation of Your Earnings

After the period is over your income consists of two parts:

- (1) The earnings from the group project.
- (2) The earnings from tokens you left in your private account.

Earnings from the project are calculated as follows: If the sum of all contributions from your group to the project reaches or exceeds 120 tokens then each participant will receive a payoff of 60 tokens. This is independent from the actual amount of the individual contributions. The order of the contributions also has no influence on the earnings from the project. If the sum of contributions is smaller than 120 tokens then no participant will receive a payoff from the project. In that case earnings will consist only of the remaining tokens in the private account.

Informations Regarding the Exact Procedure of the Experiment – Part 1

To make a decision about your contribution to the project type in a natural number between zero and 50 into the input screen. To confirm your contribution click on the OK-Button. As soon as you have pressed the OK-button you will not be able to revise your decision. Your contribution will be subtracted from your private account.

You will make your contribution decision on the following screen:

Periode
1 von 10
Verbleibende Zeit [sec]: 56

Sie sind Teilnehmer: orange

Ihre Ausstattung auf dem privaten Konto: 50

Ihre mögliche Auszahlung aus dem Projekt: 60

Teilnehmer	Beitrag	Ausstattung	Position	Zeit

Ihr Beitrag zum Projekt
(0 bis 50 Taler):

OK

Noch benötigter Betrag, um das Projekt erfolgreich durchzuführen: 120

Each participant of your group has one minute (60 seconds) to make his decision. As soon as you confirm your decision by clicking the OK-Button, your contribution will be announced to the other participants in the upper right corner of the screen. In the same way, you will be informed about all previous contribution decisions. It is up to you to choose the point in time at which you make your contribution decision and therefore also the point in time when it is announced to the other members of your group. If all participants announce their decisions before the 60 seconds run out you will have to wait until the end of the 60 seconds for the experiment to continue.

In addition to the 60 seconds all participants will have 10 seconds to familiarize themselves with the screen. The timer will therefore start at 70 seconds. During the first ten seconds none of the participant can make a decision.

If a participant announces a decision during the last 20 seconds before time is over (that is, after the 50th second) then the time left for this period will be expanded by 20 seconds. This is to ensure that participants which have not yet made their decision are able to react to the decision. Each additional decision will increase the available time by an extra 20 seconds.

Once the time is over no decisions can be made anymore. All participants who have not made a decision by the end of the time will contribute zero tokens to the project. The following income screen will inform you about the total amount of contributions of all participants of the group to the project (including your own contribution). Additionally you can see how many tokens you earned in this period.

The Income Screen:

Periode 1 von 10		Verbleibende Zeit [sec]: 17		
Das Projekt:				
Teilnehmer.	Beitrag	Ausstattung	Position	Zeit.
gelb	xx	50	1	xx
weiß	xx	50	2	xx
orange	xx	50	3	xx
blau	xx	50	4	xx
<div style="text-align: center;"> <p>Sie waren Teilnehmer: orange</p> <p>Ihr Beitrag zum Projekt: XX Taler</p> <p>Das Projekt erhielt folgende Anzahl an Talern: XX Taler</p> <p>Ihre Auszahlung aus dem Projekt: XX Taler</p> <p>Ihr privates Konto:</p> <p>Im privaten Konto verbleiben: XX Taler</p> </div>				
Ihr Einkommen in dieser Periode beträgt somit: XX Taler				
<input type="button" value="OK"/>				

At the end of each period the contributions to the project are reset to zero. Afterwards the new period starts with a new endowment of 50 tokens.

Example 1: Participant “Orange” contributes **22 tokens** after 12 seconds. “Blue” contributes **35 tokens** at 34 seconds. “White” contributes **28 tokens** after 53 seconds. This increases the remaining time by 20 seconds until the 90th second. “Yellow” decides on a contribution of **38 tokens** at the 83th second. Therefore the sum of contributions to the project is **123 tokens**. Each participant of the group receives a payoff of 60 tokens from the group project. Assume you are participant “Yellow”. Twelve tokens ($=50-38$) stay in your private account after the contribution to the project. In addition to the payoff from the project your income for this period is $60+12=72$ tokens.

Example 2: Participant “White” contributes **0 tokens** as the first one. “Yellow” contributes **38 tokens** as the second one, “Blue” announces a contribution of **47 tokens** as the third one and “Orange” decides as the fourth one on a contribution of **35 tokens**. Therefore the sum of contributions to the project is **120 tokens**. Each participant in your group earns his payoff of 60 tokens from the project. Assume you are participant “White”. 50 tokens ($=50-0$) are left in your private account after your contribution. Together with the payoff from the project, your income for this period is therefore $60+50=110$ tokens.

Example 3: Participant “Yellow” decides on a contribution of **35 tokens** as first. “Blue” announces his decision to contribute **12 tokens** as second. “White” contributes **24 tokens** as third and “Orange” decides as fourth on a contribution of **0 tokens**.

Therefore the sum of contributions to the project is **71 tokens**. No participant in your group receives a payoff from the project. Assume you are participant “White”. 26 tokens (=50-24) are left in your private account. In addition to the payoff from the project your earnings in this period are therefore $0+26=26$ tokens.

If you have any questions, please raise your hand.

Control Questions ?- Part 1

Please fill in the gaps!

Question 1: Assume you are “Yellow”. So far, in your group,
“Blue” has contributed 33 tokens as the first,
“Orange” has contributed 41 tokens as the second.
You contribute 10 tokens as the fourth. After you,
“White” contributes 36 tokens as the fourth.

Sum of contributions to the project:

Your payoff from the project:

Amount left on your private account:

Your period earnings:

Question 2: Assume you are “White”. So far,
“Orange” has contributed 42 tokens as the first.
You contribute 38 tokens as the second. Following you,
“Blue” contributes 13 tokens as the third (after 53 seconds) and
“Yellow” contributes 21 tokens as the fourth (after 86 seconds).

Sum of contributions to the project:

Your payoff from the project:

Amount left on your private account:

Your period earnings:

Question 3: Assume you are “Orange”. The other participants have already contributed:

“White” as the first 24 Tokens,

“Yellow” as the second 10 Tokens,

“Blue” as the third 36 Tokens.

(a) What are your earnings if you contribute 50 tokens to the project?

(b) What are your earnings if you contribute 0 tokens to the project?

Before the 10 Periods will start there will be two test periods so that you can familiarize yourself with the procedure of the experiment. Just as in the payoff-relevant periods you can contribute at any point in time. The decisions of the other participants will be simulated by the computer. The contributions of the computer will be represented here by the word “Number” instead of an actual amount.