Simultaneous versus Sequential Public Good Provision and the Role of Refunds — An Experimental Study*

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May 6, 2008

Abstract

We experimentally study contributing behavior to a threshold public good under simultaneous and sequential voluntary contribution mechanisms and investigate how refund policies interact with the mechanism. We find that, for a given refund rule, efficiency is greater under a sequential contribution mechanism than under a simultaneous contribution mechanism. Furthermore, for a given order of contributions, we find that full refund unambiguously achieves higher efficiency in the simultaneous mechanism while this is not the case in the sequential mechanism.

*We thank Rachel Croson, Rajiv Sarin and Lise Vesterlund, two anonymous referees and the Co–editor, Jim Andreoni, for helpful comments and suggestions. Gronberg thanks the Private Enterprise Research Center at Texas A&M University and the State of Texas Advanced Research Program for financial support. Contact: Brit Grosskopf, Texas A&M University, 4228 TAMU, College Station, TX 77843–4228, Email: `bgrosskopf@econmail.tamu.edu`.

1 Introduction

Conventional economic wisdom holds that the private provision of public goods leads to an inefficient allocation of resources. For public goods with a variable quantity, inefficiency of the predicted and realized outcomes seems firmly established (see Bergstrom, Blume, and Varian (1986) for theoretical predictions and Ledyard (1995) for a survey of the laboratory research).

For the case of threshold public goods, however, theoretical and experimental studies suggest that private provision can lead to efficient outcomes.[1] Bagnoli and Lipman (1989) show theoretically that there exists an efficient equilibrium in a game of simultaneous voluntary contributions to a threshold public good when a full refund is offered if contributions do not meet the threshold level (or so–called provision point). However, experimental papers which test this theoretical prediction provide conflicting evidence. Bagnoli and McKee (1991) find strong support, while Isaac, Schmidtz and Walker (1989) and Mysker, Olson, and Williams (1996) find only weak support for the hypothesis of successful public good provision via simultaneous contributions with full refund.[2] In a comparative analysis of experiments on threshold public good provision Croson and Marks (2000) find that contributions depend on the Step Return (SR): the higher the SR the higher the contributions.[3]

The above mentioned theoretical as well as experimental papers assume that contributions are made simultaneously. Clearly, many real world voluntary contribution processes are not conducted simultaneously. Instead, contributions are collected sequentially and early contributions are made public. For example, as reported by Dorsey (1992), the Public Broadcasting System

[1] A threshold public good can only be provided if a given threshold of contributions is met. Such public goods are also referred to as discrete or fixed quantity public goods and have been justified as being an appropriate description of the lumpy nature of many public goods (i.e. parks, roads, bridges, community libraries etc.). Andreoni (1998) argues that the fixed costs associated with a number of charitable goods, such as basketball arenas and school buildings, make threshold public goods models relevant to understanding capital fund campaigns.

[2] Observed frequencies of the successful provision of the threshold public good in those three papers are: Bagnoli and McKee (1991) – 85.7%, Isaac, Schmidtz and Walker (1989) – 43% to 57% depending on the threshold and Mysker, Olson and Williams (1996) – 60%.

[3] The concept of SR is similar to the concept of Marginal–per–Capita–Return (MPCR) for non–threshold public goods.

quarterly announces a time period within which contributions will be collected. During this period, the total contribution level is announced and frequently updated. Churches announce organ or building fund campaigns and provide weekly updates on contributions in the Sunday bulletin. A recently started website (www.thepoint.com) advertises to provide a platform for group action, helping to make things happen that one couldn't accomplish alone. Anyone can start a campaign that promises to take action if a certain threshold of either money or members is met. The website keeps up–to–date information on the achievement towards the campaign goal. The founder Andrew Mason explains the advantage of the site's mechanism with "By delaying action until you know that you have all the pieces in place for the action to be successful and get the outcome that you desire, you're reducing the risk of acting as a group."

The reasons for the existence of sequential fund drives are manifold. The sequential nature might overcome information asymmetries regarding the value of the underlying public good. Sequential contributions can also help to overcome the coordination problem that might exist when donors are faced with simultaneous contributions. The earlier mentioned mixed results regarding simultaneous provision can be reinterpreted as different levels of success in solving the underlying coordination problem given the multiplicity of equilibria in such games. If contributions are made sequentially, no such coordination problem exists.

Some theoretical work (e.g., Varian (1994) and Admati and Perry (1991)) predicts an inefficient allocation of resources even for a contributions mechanism that uses sequential contributions. Experimental studies, however, have shown that a sequential mechanism can improve public good provision relative to a simultaneous mechanism in linear public good games and threshold public good games without a refund.[4] Dorsey (1992) documents a higher rate of successful provision of the threshold public good if real time adjustments of the voluntary contributions can be made. Erev and Rapoport (1990) find evidence in favor of the sequential contributions mechanism in the case of a threshold public good when no refund is offered and individual contributions are either all or nothing (see also Rapoport and Erev (1994)).

[4]Admati and Perry (1991) also show that the unique subgame–perfect equilibrium in a sequential threshold public goods game with full refund leads to an efficient outcome.

Our paper aims at exploring the effects the order of contributions has on individual contributions and efficiency of the provision of a threshold public good. We are not aware of any study that compares these two orders when a full refund is offered. We are, furthermore, interested in whether a refund rule affects simultaneous and sequential contributions mechanisms in the same manner. While Isaac, Schmidtz and Walker (1989) analyze the effects of refunds in a simultaneous setting, we are unaware of an existing study that compares behavior in a sequential setting with and without a refund.

Our experimental implementation compares contributing behavior in a simultaneous mechanism with and without a full refund to that of a sequential mechanism with and without a full refund. We find that, for a given refund rule, the sequential contributions mechanism unambiguously provides the public good more often and more efficiently. This performance advantage is greater when no refund is offered than when a full refund is offered. Introducing a full refund unambiguously increases efficiency of the simultaneous mechanism. However, this is not the case in the sequential mechanism.

The paper is structured as follows, section 2 introduces our experimental design and the choice of parameters. Section 3 summarizes the theoretical predictions. Section 4 discusses the experimental results and section 5 concludes. Appendix A illustrates the experimental interface.

2 Experimental Design

We study a simple, common, provision point public goods game. Individuals are given an endowment w_i of a private good x. They can make contributions c_i of their endowment towards the provision of a fixed quantity of the public good g. The public good is provided if and only if the sum of the contributions from all players is greater than or equal to the cost of the public good P_g. The cost of the fixed–size public project thus defines the provision point for the game. The payoff structure is of the linear symmetric threshold form (see Ledyard (1995)). The payoff of group member i (of group size n) is given by

$$v_i = w_i - c_i + g \quad \text{if} \quad \sum_{j=1}^{n} c_j \geq P_g$$
$$= w_i - \theta c_i \qquad\qquad \text{otherwise,}$$

where θ is a parameter that captures the refund policy if the public good is not provided because of insufficient contributions of the group members. θ is equal to 0 under the full refund rule and equal to 1 under the no refund rule. Note that excess contributions are not rebated.[5] In all of our experiments, we set $w_i = 5$ tokens, $g = 6$ tokens, $P_g = 12$ and $n = 4$. We employed a 2×2 between–subject design, in which we varied whether participants simultaneously or sequentially made their contributions as well as whether a full refund was offered or not. Table I summarizes the details.

In each experimental session (with one cohort per session) we had 12 subjects participate in 20 rounds of a repeated one–shot game.[6] In each round, the 12 subjects were randomly regrouped into groups of 4. After each round, participants in all treatments were informed about the individual contributions of their group members.

Table I:
The 2×2 Experimental Design

		Order of Contributions	
		Simultaneous	Sequential
Refund	No Refund	3 cohorts	3 cohorts
Policy	Full Refund	3 cohorts	6 cohorts

In the simultaneous contribution institution, agents simultaneously make contributions to the public good. In the sequential contribution institution,

[5]The impact of alternative rebate rules within a threshold public goods environment is studied by Marks and Croson (1998). Offering full refund differs from offering rebates. While rebate rules specify how excess contributions over the threshold amount are distributed, refund rules specify what happens to contributions in case the threshold is not met.

[6]The experimental sessions continued for another 20 rounds with a different provision point. For results on these see the working paper version of Coats and Gronberg (2001). Experimental results as well as average earnings reported here are for the first 20 rounds only.

participants move in a randomly assigned sequence and each participant is informed about the amount that each previous participant has contributed.

We use the same presentation for the simultaneous as well as the sequential contributions mechanism, so that the only differences in presentation reflect strategic differences in the games (for the computer interface see Appendix A).

We randomly reassign groups every period in an attempt to minimize repeated game effects and thus to approximate the theoretical environment of a one–shot game (see Andreoni (1988) and Andreoni and Croson (2001) for a discussion of rematching protocols in public goods experiments). When subjects are randomly rematched each period (and know and believe this) it is much harder for group effects to develop. Strangers have little incentive to try to signal to other participants and punishment of other participants is made impossible. The random matching protocol also reduces potential fairness concerns. In the sequential contributions mechanism, the subgame perfect equilibrium always favors the first two movers. Subjects may consider this unfair and try to come up with allocations which are more fair than the subgame perfect equilibrium. However, subjects are randomly rematched and randomly re–ordered each period so they have an equal chance every period of being assigned any order in the sequence. Therefore, everyone has a fair chance of being assigned to be the designated first mover and subjects have less reason to regard the subgame perfect equilibrium as unfair.

Finally, given concerns for framing or presentation effects, we implemented the design in an abstract form while still capturing the essential theoretical elements of an experimental public goods environment. The presentation expresses the games in neutral terms, without explicit reference to the public goods nature of the environment. Terms such as 'group account,' 'cooperation,' 'contribution,' and 'public good' are not used.

The experiments were conducted at the Economic Research Laboratory at Texas A&M. Participants were undergraduate students at Texas A&M recruited from introductory economics or business classes. Payoffs were accumulated over all 20 rounds. Each experimental token was worth \$0.0625. On average, participants earned \$7.61.[7] The main screen of the computer

[7] If the threshold public good was efficiently provided in each round, participants would

interface recorded a balance in cash earnings at all times so that subjects remained aware of the connection between their choices and their cash earnings.

3 Theoretical Predictions and Hypotheses

3.1 Aggregate Performance Measures

In evaluating the performance of the different mechanisms we will predominantly focus on efficiency. Additionally, we will report on contribution levels and on the number of times the public good was succesfully provided. A comparison of contributions alone, however, would not suffice given the threshold nature of the public good. While giving a qualitative idea of the performance, contributions could either fall short of the threshold or exceed the threshold. Our experimental design employed a *no rebate* rule, i.e. excess contributions are simply wasted. Marks and Croson (1998) have shown that the variance of contributions is the lowest under such a rebate rule. Since we wanted to focus on sequentiality and refund, we felt that we did not want to introduce additional variance due to other rebate rules.[8] We will first define efficiency and success and then state our hypotheses with respect to efficiency.

Efficiency Efficiency is measured as the percent of the maximum feasible surplus for public good provision, where maximum surplus is calculated as $n \cdot g - P_g = 4 \cdot 6 - 12 = 12$. Public good provision can be less than one hundred percent efficient for either of two reasons. First, contributions may fail to reach the provision point and, second, contributions may exceed the provision point. If contributions fail to reach the provision point, then efficiency is zero percent under the zero contribution outcome and under any

have earned \$10. No show–up fee was paid. The experiments were conducted in 1996. The purchasing power of \$10 in 1996 was \$13.21 in 2007.

[8] Marks and Croson (1998) study the effects of three different rebate rules on voluntary contributions to a threshold public good: no rebate, proportional rebate and utilization rebate. While excess contributions are distributed back to contributors proportional to their individual contributions under proportional rebate, another public good is provided in a continuous manner using the excess contributions under utilization rebate. Marks and Croson (1998) find that while contributions are higher under utilization rebate than under the other two rebate rules, the frequency with which the threshold public good is provided does not vary with the rebate mechanism.

other vector of insufficient contributions with a money–back guarantee; but without a full refund such outcomes (other than zero contribution) will result in negative efficiency since part of the original endowment will be lost. If contributions exceed the provision point, the level of efficiency depends on the number of wasted tokens. For example, if all group members contribute all of their tokens then eight tokens are wasted and the outcome is thirty–three percent efficient. That is, efficiency (E) is measured as:

$$E = \begin{cases} (24 - \sum_{i=1}^{4} c_i)/12 & \text{if } \sum_{i=1}^{4} c_i \geq 12, \\ 0 & \text{if } \sum_{i=1}^{4} c_i < 12 \text{ with a full refund,} \\ (0 - \sum_{i=1}^{4} c_i)/12 & \text{if } \sum_{i=1}^{4} c_i < 12 \text{ with no refund.} \end{cases}$$

For both institutions we report on realized percent efficiency given the actual groupings of subjects that take place during the experiment. In the sequential institution this seems the natural choice. Subjects make their choices sequentially in each period and the realized outcomes depend entirely upon the choices specific to the actual groups. One could argue that for the simultaneous institution this is not necessarily the case, since we can think of four hundred and ninety–five equally likely groupings of the twelve observed choices each period.[9] However, since subjects get information about all individual contributions in their group at the end of each round, we decided to stick with the observed (i.e. actually realized) efficiency even in the simultaneous institution.[10]

Success Rate A second measure of performance is simply the rate of successful provision of the public good. This measure, however, fails to incorporate the importance of the way in which provision is successful or

[9] For example, suppose six players select a contribution of 2 tokens and six players select a contribution of 4 tokens. These contributions are selected prior to the random partitioning of the population into three stage game populations of size four (note that six 4's and six 2's is a population–type equilibrium to the random matching game). A contribution of 2 is a best response (expected payoff–maximizing) against six 4's and five 2's and a contribution of 4 is a best response against six 2's and five 4's. The expected efficiency from a random allocation of 12 players into three groups of 4 players for a population of strategies of six 2's and six 4's is 69% (the probability of an efficient grouping of two 2's and two 4's is 0.48).

[10] We did this because it is likely that individual behavior is more affected by the outcomes reported to the individuals than the hypothetical possible outcomes.

unsuccessful according to the considerations discussed above, especially in the simultaneous institution. Therefore, we discuss success as an independent performance concept from efficiency.

3.2 Simultaneous vs. Sequential Contributions

The public goods game with simultaneous contributions and no refund has multiple pure strategy Nash equilibria. Any contribution vector (c_1, c_2, c_3, c_4) with $\sum_j = 12$ constitutes an efficient equilibrium. The only inefficient equilibrium is given by the contribution vector of $(0, 0, 0, 0)$. In contrast, in the public good game with sequential contributions and no refund there exists a unique subgame perfect equilibrium which is efficient and given by the contribution vector $(0, 2, 5, 5)$.[11] Given the multiplicity of equilibria in the simultaneous case and the uniqueness in the sequential case we conjecture that efficiency is higher in the sequential case. In fact, Erev and Rapoport (1999) already find that contributions are higher when they are made sequentially. Our first hypothesis can be seen as a robustness check and an extension to the case when contributions are quasi–continuous.

> ***Hypothesis 1:*** *Efficiency is higher when contributions are made sequentially than when they are made simultaneously when no refund is offered.*

Allowing for full refund adds multiple inefficient equilibria to the already existing multiplicity of efficient equilibria in the simultaneous game.[12] In contrast, the introduction of full refund does not change the uniqueness of the subgame equilibrium prediction in the case of sequential contributions. We therefore hypothesize that efficiency in the simultaneous game will again be hurt by the existing coordination problem posed by the multiplicity of equilibria. We therefore expect our first hypothesis to extend to the case when a full refund is offered.

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[11] In the event that earlier movers do not make subgame perfect choices, later movers still have an iterated dominant strategy to make the minimum contribution for which the remaining participants are capable of providing the necessary amount to provide the public good.

[12] Any contribution vector that does not sum up to 12, in which the sum of contributions would remain less than 12 if any single player chooses to contribute her entire endowment of 5 (e.g. $(2, 2, 2, 2)$ and $(0, 1, 2, 3)$) constitutes an inefficient equilibrium.

Hypothesis 2: *Efficiency is higher when contributions are made sequentially than when they are made simultaneously when a full refund is offered.*

3.3 No Refund vs. Refund

As conjectured by Isaac, Schmidtz and Walker (1989) (henceforth ISW) for a similar environment, for the efficient equilibrium to occur, individual group members might need a credible guarantee that others contribute as well. Such assurance is not needed in the case of a full refund. This means that even risk averse participants should feel safe contributing when a full refund is offered which is not necessarily the case without a refund. ISW therefore predicted and observed lower contributions and hence lower efficiency in the no refund case compared to the full refund case. Our third hypothesis is a robustness check of their results.

Hypothesis 3: *Efficiency in the simultaneous case with full refund is higher than efficiency in the simultaneous case without a refund.*

As mentioned before the introduction of a full refund does not change the unique subgame perfect equilibrium prediction. We therefore conjecture that efficiency in the sequential case is not affected by the introduction of a full refund.

Hypothesis 4: *Efficiency in the sequential institution is the same under either refund rule.*

3.4 Interaction of Sequentiality and Refund

Given the predicted (and observed by ISW) higher efficiency in the simultaneous game with full refund (as compared to the case without a refund) and the new prediction of no difference in efficiency between the sequential case with and without a refund, we predict a bigger effect of the order in the no refund case. Our next hypothesis states this more precisely.

Hypothesis 5: *The relative increase in efficiency when comparing sequential with simultaneous contributions is greater when no refund is offered that when a full refund is offered.*

Hypotheses 3 and 4, taken together, imply that the overall increase in efficiency predicted by the introduction of a full refund rule is greater in the simultaneous game than in the sequential game.

Hypothesis 6: *The relative increase in efficiency when comparing a no refund to a full refund rule is greater when contributions are made simultaneously than when they are made sequentially.*

4 Experimental Results

4.1 Aggregate Results

Tables II – VII report on aggregate results (aggregated over all rounds and all sessions). These are for illustrative purposes only and any statistical tests are done on session level data.

In order to test our first two hypotheses, we compare efficiency in both institutions for a given refund rule.[13] Conducting robust rank order tests on session level data we find that observed efficiency in the sequential institution is significantly higher than in the simultaneous institution when no refund is offered (p–value < 0.01). The same holds if we compare efficiency in both institutions under the full refund policy (p–value < 0.01).[14,15] Our data support $H1$ and $H2$.

TABLE II:
OBSERVED EFFICIENCY

	Simultaneous	Sequential
No Refund	-13.2%	50.1%
Full Refund	42.9%	65.0%

[13] For the non–parametric tests used in this paper see Siegel and Castellan (1988).

[14] The lowest efficiency rate observed of all sessions in the sequential institution under full refund (no refund) is higher than the highest observed efficiency in the simultaneous institution under full refund (no refund). We report p–values associated with such approximately infinitely large test statistic as $p < 0.01$.

[15] This result holds even if we split the data into the first 10 rounds and the last ten rounds.

Conducting robust rank order tests on session level data for the observed efficiency in the simultaneous institution, we find strong support for our third hypothesis. Efficiency is higher in the simultaneous institution when a full refund is offered (p–value < 0.01).[16] As for the sequential institution, we find support for our fourth hypothesis. Efficiency is not significantly affected by the refund rule (robust rank order test, $\grave{U} = -1.28624$, two–tailed p–value > 0.2).[17]

While the sequential institution unambiguously achieves more efficient outcomes than the simultaneous institution when comparing across the same refund policies, the refund policy is crucial. Sequential institutions per se do not dominate simultaneous institutions in achieving higher efficiency. We observe that the achieved efficiency of the sequential mechanism without a refund is not different from the achieved efficiency of the simultaneous mechanism with a full refund (robust rank order test, $\grave{U} = -0.53033$, two–tailed p–value > 0.2).[18]

In order to understand the differences in observed efficiency, we separate the reasons for an efficiency loss. If positive contributions are made, efficiency can be lost due to two reasons, (A) undercontribution and (B) overcontribution. Efficiency is clearly also lost when all members in the group contribute zero. When no refund is offered, (A) and (B) can happen in the simultaneous case. In the sequential case, overcontributions should not happen and an efficiency loss can, arguably, only happen due to (A). Table III classifies group contribution choices into four efficiency classes. It illustrates that the sequential contributions mechanism differs from the simultaneous one in three ways: (1) fewer groups exhibit undercontributions, (2) fewer groups exhibit overcontributions and (3) more groups achieve 100%–efficiency. Table III also makes clear that the proportion of undercontributions is affected by the refund rule in the simultaneous mechanism but not in the sequential one. In fact, offering a full refund reduces the

[16] In fact, efficiency in each session under the full refund policy is higher than the highest efficiency ever achieved under the no refund policy.

[17] This effect is driven by behavior in the last 10 rounds, since efficiency is higher under the full refund policy than under the no refund policy for the first 10 rounds (robust rank order test, $\grave{U} = -2.91218$, $p = 0.0036$, two–tailed).

[18] This is due to the high variance across sessions in the observed efficiency in the sequential institution without refund.

proportion of undercontributions and increases the proportion of overcontributions in the simultaneous mechanism while those are essentially unaffected in the sequential mechanism.

Table III:
Group Contributions By Efficiency Class

		(A) Under-contribution	(B) Over-contribution	Zero by all group members	100% efficiency
No	SIM	69.4% $\left(\frac{125}{180}\right)$	11.1% $\left(\frac{20}{180}\right)$	4.4% $\left(\frac{8}{180}\right)$	15.0% $\left(\frac{27}{180}\right)$
Refund	SEQ	33.3% $\left(\frac{60}{180}\right)$	0.6% $\left(\frac{1}{180}\right)$	3.9% $\left(\frac{7}{180}\right)$	62.2% $\left(\frac{112}{180}\right)$
Full	SIM	53.3% $\left(\frac{96}{180}\right)$	26.1% $\left(\frac{47}{180}\right)$	0% $\left(\frac{0}{180}\right)$	20.6% $\left(\frac{37}{180}\right)$
Refund	SEQ	34.7% $\left(\frac{125}{360}\right)$	0.6% $\left(\frac{2}{360}\right)$	0.3% $\left(\frac{1}{360}\right)$	64.4% $\left(\frac{232}{360}\right)$

Comparing success rates across the different mechanism (see Table IV), we again find that the sequential mechanism outperforms the simultaneous one for each refund rule (robust rank order test, $\grave{U} = -2.34787$, one–tailed p–value $= 0.1$, no refund and p–value < 0.01, refund, respectively).[19] As for comparing refund rules, we find that the threshold public good is not significantly more often provided when contributions are made simultaneously and full refund is offered compared to when no refund is offered (robust rank order test, $\grave{U} = -0.53033$, two–tailed p–value > 0.2). This is due to the higher variance in the session level data of success rates when no refund is offered. One session achieved the highest success rate of all simultaneous contribution sessions.[20] The introduction of a full refund also does not influence the successful provision of the public good when contributions are made sequentially (robust rank order test, $\grave{U} = 0.149709$, two–tailed p–value > 0.2).

Finally, if the intention of designing one institution over another is to increase the number of times the public good is provided, we find that even a

[19] In fact, the success rate in each session with sequential contributions is higher than the highest success rate ever achieved under simultaneous contributions.

[20] Since we are using the most conservative statistical approach, this session has a strong influence as one of the three independent observations for the no refund case that are compared with three independent observation for the full refund case.

sequential institution with no refund unambiguously provides the public good more often than a simultaneous institution with full refund (p–value< 0.01).[21]

TABLE IV:
OBSERVED SUCCESS RATES

	Simultaneous	Sequential[22]
No Refund	26.1%	62.8%
Full Refund	46.7%	65.0%

Hypotheses 5 and 6 refer to the interaction of order and refund rule. From Tables II and IV we see that efficiency increases by 63.3% when changing from the simultaneous mechanism to the sequential mechanism under the no refund rule. The success rate goes up by 36.7%. In contrast, when a full refund is offered, the increase in efficiency is only 22.1% and the success rate goes up by only 18.3%, supporting Hypothesis 5. Conducting robust rank order tests on the difference in differences confirms that the increase in efficiency is greater with simultaneous contributions than with sequential contributions ($\grave{U} = 4.717101$, p–value < 0.01). The increases in the success rates are not significantly different from one another ($\grave{U} = 1.032371$, p–value > 0.10). Given that we find a significant impact of the refund rule for the simultaneous mechanism but not for the sequential mechanism, we can conclude that changing from the no refund to the full refund rule in the simultaneous mechanism increases efficiency more than changing the refund rule in the sequential mechanism indicating support for Hypothesis 6.[23]

[21] All simultaneous sessions with refund have a lower success rate than the lowest success rate observed for a sequential mechanism without refund.

[22] Note that efficiency in the sequential institution in the full refund case should, theoretically speaking, be identical to the success rate. This is almost the case. However, we observed 2 players, who were the last to choose in their group, to add 5 to a total sum of 8 by the others, thereby overshooting the target by 1 token and losing some efficiency.

[23] If we analyze average earnings of participants instead of achieved efficiency, we find support for all of our hypotheses. In particular, we find that under a sequential mechanism participants earn significantly more than under a simultaneous one for a given refund rule ($p < 0.01$). The session with the highest average earning of the simultaneous mechanism without refund (with refund) has a lower average than the lowest earning session in the sequential mechanism without refund (with refund). While the introduction of a full refund increases average earnings significantly in the simultaneous mechanism ($p < 0.01$)

4.1.1 Contributions

Table V summarizes the observed frequencies of three "refined" equilibria and two focal contribution choices. The refinement leading to the first two equilibria comes from the fact that they are both symmetric. Given that it is common knowledge that everyone has the same endowment (and payoffs are calculated for all in the same way) it seems reasonable to expect equilibria to be symmetric with respect to the contributions of the individual group members. Symmetric equilibria are behaviorally supported by the assumption that participants are concerned with fairness (e.g. Bolton and Ockenfels, 2000 and Fehr and Schmidt, 1999) since all participants would be contributing the same amount. The third contribution vector, (0,2,5,5), constitutes the unique subgame perfect equilibrium in the sequential game with and without a refund.

TABLE V:
OBSERVED FREQUENCY OF SOME CONTRIBUTIONS

		(0,0,0,0)	(3,3,3,3)	(0,2,5,5)	0	3
No Refund	Simultaneous	4.4%	10.6%	0%	34.31%	36.94%
		$(\frac{8}{180})$	$(\frac{19}{180})$		$(\frac{247}{720})$	$(\frac{266}{720})$
	Sequential	3.9%	1.1%	7.2%	24.72%	17.22%
		$(\frac{7}{180})$	$(\frac{2}{180})$	$(\frac{13}{180})$	$(\frac{178}{720})$	$(\frac{124}{720})$
Full Refund	Simultaneous	0%	6.1%	0%	3.61%	49.31%
			$(\frac{11}{180})$		$(\frac{26}{720})$	$(\frac{355}{720})$
	Sequential	0.3%	1.7%	0%	14.31%	18.68%
		$(\frac{1}{360})$	$(\frac{6}{360})$		$(\frac{206}{1440})$	$(\frac{269}{1440})$

Examining Table V, there are a number of interesting observations to be made. (1) The number of times any of the refined equilibria are chosen is relatively low throughout. (2) The observed frequency of choices of the efficient and fair equilibrium of (3,3,3,3) is highest in the simultaneous games. Tests of equality of proportions confirm that this proportion is higher in the

the refund rule has no effect on average earnings in the sequential mechanism (robust rank order test statistic $\grave{U} = -1.2862$). Average earnings of the lowest earning session under the simultaneous mechanism with refund are higher than average earnings in the highest earning session under the simultaneous mechanism without refund.

simultaneous game when compared to the sequential one under either refund rule (z–statistics are 3.82 (without a refund) and 2.79 (with a refund) respectively).[24] (3) The subgame perfect equilibrium is only ever chosen in the sequential game without a refund. While the uniqueness of the subgame perfect equilibrium doesn't seem to succeed in making it the focal choice it seems to lure choices away from the fair equilibrium. (4) The inefficient symmetric equilibrium $(0, 0, 0, 0)$ is chosen roughly as often in the simultaneous game as in the sequential game under either refund rule (z–statistics are 0.26, without a refund, and -0.71, with a refund respectively). (5) As expected, the assurance problem does not arise when a full refund is offered. Even risk averse participants can safely contribute and we do not observe any groups where all players choose zero in the simultaneous game and only one (out of 360) in the sequential game. (6) On the individual level we see that introducing a refund leads to far less choices of zero and many more choices of 3 in the simultaneous game. However, the introduction of a full refund only cuts down on the zero choices while not increasing the choices of 3 in the sequential game.

TABLE VI:
AVERAGE CONTRIBUTIONS BY PLAYER ORDER
(Sequential Game)

	1st player	2nd player	3rd player	4th player
No Refund	2.08	2.42	2.18	2.37
Full Refund	1.36	2.11	3.37	4.02

Table VI illustrates average contributions depending on the order in which players made their contributions in the sequential institution. Interestingly, average contributions in the no refund treatment are much more symmetric

[24] The specific test statistic is $z = (p_1 - p_2)/S_{p_c}$, where p_i is the proportion of contribution vectors of (3,3,3,3) in subsample i, and $S_{p_c} = \sqrt{p_c(1-p_c)(\frac{1}{N_1} + \frac{1}{N_2})}$ is an estimate of the standard error of the difference in proportions, $p_1 - p_2$. p_c is an estimate of the population proportion under the null hypothesis of equal proportions, $p_c = (p_1 N_1 + p_2 N_2)/(N_1 + N_2)$, where N_i is the total number of contribution vectors in subsample i (see Glasnapp and Poggio, 1985).

across the four players in a group than in the treatment with a refund. First players in the no refund treatment contribute significantly more than their equally positioned counterparts in the treatment with a refund (robust rank order test, $\grave{U} = 2.912176$, one tailed $p = 0.0018$). The same holds for second players (robust rank order test, $\grave{U} = 2.544079$, one tailed $p = 0.0055$). Third and fourth players, however, contribute significantly more in the treatment with a refund.[25] Qualitatively speaking, it seems as if equilibrium predictions are more born out when a full refund is offered. One possible explanation could be that first players feel less guilty about contributing less in the full refund treatment because they know that later players will get their contributions reimbursed if the threshold is not met. This makes fairness considerations seem stronger in the case without a refund. For a different interpretation of first player's behavior see Coats and Neilson (2005) who focus on reciprocity motivations.[26]

Table VII:
Contributions in line with Best Response Predictions
(Sequential Game)

	1st player	2nd player	3rd player	4th player
No Refund	20.56% ($\frac{37}{180}$)	30.56% ($\frac{55}{180}$)	52.78% ($\frac{95}{180}$)	87.22% ($\frac{157}{180}$)
Full Refund	34.17% ($\frac{123}{360}$)	33.33% ($\frac{120}{360}$)	65% ($\frac{234}{360}$)	68.06% ($\frac{245}{360}$)

Table VII summarizes how often players actually best respond depending on what previous movers have contributed. We can see that the difference between the sequential game without a refund and the sequential game with a refund can be found in the behavior of the first and last players. First movers in the treatment with a full refund are significantly more likely to choose zero than their counterparts in the treatment without a refund (test of equality of proportions, z–statistic$= -3.27$). However, fourth movers are

[25] The lowest average contribution of all sessions with refund is higher than the highest contribution of all sessions without refund for third as well as fourth players.

[26] Coats and Neilson (2005) interpret higher contributions of early movers in the sequential mechanism without a refund as avoidance of negative reciprocity of later movers. Early movers know that later movers have the capacity to punish low contributions under the no refund rule and hence contribute more in that case.

significantly more likely to best respond when no refund is offered (test of equality of proportions, z–statistic$= 4.81$). Arguably, this could be driven by the fact that it is more costly to make mistakes when contributions are not refunded. Similarly, it is less costly for the fourth player to "express" her dislike of the rather unequal contribution distribution if a full refund is offered. Second movers are equally likely to choose best responses (test of equality of proportions, z–statistic$= -0.65$). Third movers are more likely to best respond in the sequential game with a full refund (test of equality of proportions, z–statistic$= -2.74$).

Table VIII shows that failures to follow the best response prediction due to overcontribution are declining as players are moving later. This holds in both refund conditions. Clearly, first movers can only err in the direction of overcontribution. Last movers deviations, whether they are overcontributions or undercontributions, are choices in dominated strategies.

Table VIII:
Contributions not in line with Best Response Predictions due to Overcontributions
(Sequential Game)

	1st player	2nd player	3rd player	4th player
No Refund	100% ($\frac{143}{143}$)	86.40% ($\frac{108}{125}$)	57.65% ($\frac{49}{85}$)	4.35% ($\frac{1}{23}$)
Full Refund	100% ($\frac{237}{237}$)	97.50% ($\frac{234}{240}$)	50.79% ($\frac{64}{126}$)	1.74% ($\frac{2}{115}$)

4.2 Individual Behavior

The aggregate analysis above ignores any individual–specific effects. We shall now report on random effects Tobit regressions estimated using individual contribution data.[27] Tables IX and X report on the results. The dependent variable is each participant's contribution, naturally censored to

[27]We were not able to cluster for session level effects in the random effects Tobit regressions. However, an alternative random effects GLS regression does not account for the censoring of the data (naturally the contributions lie between 0 and 5). Since about one third of our data are censored, we decided to run random effects Tobit regressions. Additional error correlations within a session (which would be accounted for in a clustered regression) should only affect the efficiency and not the significance of our estimates.

lie between 0 and 5. Like other studies on threshold public good games, we do not find contributions to decline over time.[28] We include a dummy variable **refund** that equals 1 if a full refund is offered, a dummy variable **previous success** that equals 1 if the public good was successfully provided in the previous round, a dummy variable **lowest contributor** that equals 1 if the subject was the lowest contributor in the group and a dummy variable **highest contributor** that equals 1 if the subject was the highest contributor in the group. We also include interactions of the treatment variable **refund** with all other variables.

TABLE IX:
RANDOM EFFECTS REGRESSION RESULTS
(Simultaneous Institution)

	RE Tobit		
constant	1.9867**		
	(0.0756273)		
refund	0.3996**		
	(0.1046488)		
previous success	3.4021	refund×success	0.5410*
	(0.1923685)		(0.2343418)
lowest contributor	-2.0580**	refund×lowest	1.0976**
	(0.1987207)		(0.2111576)
highest contributor	1.7002**	refund×highest	-0.7392**
	(0.197732)		(0.2010644)
-log likelihood	1917.2704		
Wald χ^2	518.56**		
left–censored	255		
right–censored	81		
uncensored	1032		

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

[28]We started off by also including **period** (1 – 20) and **prev_free** (equal to 1 if participant freerode in previous period) as explanatory variables. However, likelihood ratio tests confirmed that the restrictions of **period** and/or **prev_free** being equal to 0 could not be rejected. We therefore did not include these variables in the estimations that we report.

We first concentrate on the simultaneous institution and analyze differences in contributions depending on whether a refund is offered or not. We find that participants unambiguously contribute more when a full refund is offered, providing additional support for Hypothesis 3. Whether the public good was provided in the previous round or not does not affect contributions when no refund is offered. However, participants contribute more in the full refund case when the public good was successfully provided in the previous period. This seems to be driven by the lowest contributors in a group. While those low contributors usually decrease their contributions in a subsequent round, the decrease is significantly smaller in the full refund case. Interestingly, the highest contributors in a group usually contribute more in a subsequent round, however at a lower rate in the full refund case. Contributions in the full refund case get an additional boost when the public good was successfully provided in the previous round, i.e. contributions are higher in any subsequent round which is not the case when no refund is offered.[29]

We included the order in which participants make their contributions in our random effect estimations for the sequential institution. For each position we created a dummy variable and interacted the position with the refund variable. We find that the refund influences contributions differently for first movers than for later movers. We find that while third and fourth movers contribute more than first movers under either refund rule, they contribute even more under the full refund rule. This also holds for second movers who contribute significantly more than first movers under the full refund rule. Whether the public good was provided successfully seems to only matter in the full refund case where participants tend to decrease their contributions after a successful provision. It seems that introducing a full refund in the sequential mechanism changes the distribution of contributions within the groups by shifting contributions from earlier to later movers without necessarily having an overall impact.

[29] Theory does not predict such an effect. However, reinforcement models (e.g., Roth and Erev, 1995) would tend to predict such behavior. Interestingly, contributing behavior does not get reinforced in the case when risk aversion might play a role (i.e. without refund).

TABLE X:
RANDOM EFFECTS REGRESSION RESULTS
(Sequential Institution)

	RE Tobit		
constant	1.3343**		
	(0.2638)		
refund	-0.3671		
	(0.3247)		
previous success	0.1386	refund×success	-0.4661*
	(0.1967)		(0.2250)
second	0.3032	refund×second	0.9496**
	(0.2498)		(0.3076)
third	1.3029**	refund×third	1.6324**
	(0.4248)		(0.4818)
fourth	1.6454**	refund×fourth	2.6172**
	(0.4413)		(0.5110)
-log likelihood	3523.0433		
Wald χ^2	245.89**		
left–censored	360		
right–censored	413		
uncensored	1279		

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

5 Discussion

We analyze how voluntary contributions to a threshold public good are affected by institutional characteristics of the voluntary contributions mechanism. In particular, we compare efficiency in the case of simultaneous and sequential contributions. For each order of contributions (simultaneous and sequential giving), we further investigate how a full refund rule affects efficiency as compared to a no refund rule. We find that, given a refund rule, the sequential contributions mechanism unambiguously achieves higher efficiency, gives participants higher earnings and successfully provides the threshold public good more often than the simultaneous mechanism. For the no refund rule, this extends the results of Erev and Rapoport (1990), who find this to be the case for binary contributions, to a variable contribution setting. Our results are novel for the full refund case. We show that a sequential contributions mechanism yields higher efficiency, greater earnings and provides the public good more often when a full refund is offered than a simultaneous contributions mechanism with the same refund rule.

For the simultaneous mechanism we find significantly higher efficiency in the case with a full refund. These results support what others have found (i.e., Isaac, Schmidtz and Walker (1989)) for similar simultaneous contribution games. We show that those results do not extend to sequential contribution games. Surprisingly, albeit in line with theoretical predictions, the refund rule does not matter in the sequential games when efficiency and earnings are analyzed. This indifference, however, is not driven by the fact that the subgame perfect equilibrium is being chosen predominantly often. In fact, when the full refund rule is introduced, we never observe the SPE to be chosen. Qualitatively, contributions under the sequential mechanism with a full refund resemble the "unequal" nature of the SPE predictions with first movers contributing less and later movers contributing more. It seems that early movers are influenced by other–regarding preferences and the expectations of such preferences. This explanation is different from a risk averse explanation behind the effect of a full refund in the simultaneous game. There, risk averse participants contribute because they do not have to fear losing money. It seems that the expectation of others being risk averse and concerned with fairness makes early movers contribute less in the case of full refund and more otherwise. The risk aversion explanation for the simultaneous game still holds for later movers in the sequential game. These later movers contribute more when a full refund is offered.

From an applied fund–raising institutional design perspective, our results suggest that both order of contributions and refund policy matter, but that order trumps refund policy in importance. The success rate, which is the likely focal performance measure for fund–raising campaign designers, is clearly highest under sequential giving. Given a commitment to the sequential ordering, the ability to commit to refunds does not impact success rates in our environment. Given the potentially high transaction costs of implementing refunds, particularly in the case of voluntary contributions of time rather than money, the insensitivity of the sequential institution to the refund rule seems particularly important. Our sequential results do, however, come in a setting where individuals are assigned a place in the contribution order. Since most actual sequential fund–raising institutions allow the order of contributions to develop endogenously, it would be an interesting extension of our work to look at the effects of refund rules in a sequential threshold public goods game with endogenous order of play.

Appendix A: Experimental Interface

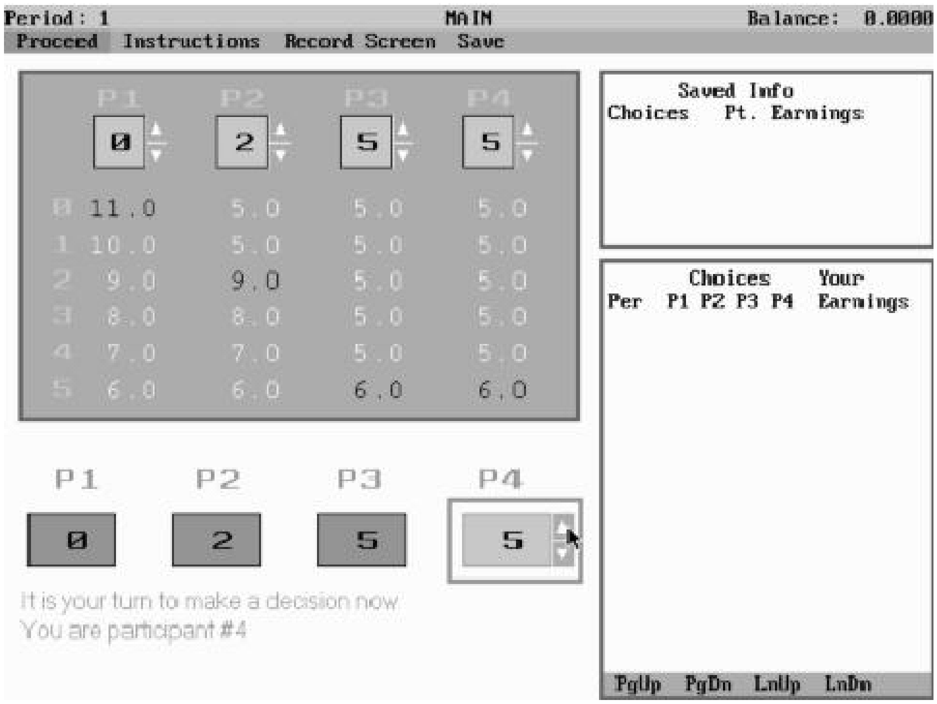

Figure A1: Example of Main Screen (here sequential with full refund)

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