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Step-Level Public Goods: Experimental Evidence

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Abstract

We analyze the provision of a step-level public good in an experiment. Specifically, we investigate how the order of moves and the introduction of a second step-level affects public-good provision. We find that the sequential-move game improves public-good provision and payoffs. An additional step-level does lead to higher contributions but the effect on public-good provision is ambiguous and insignificant. Based on an existing data set, we calibrate Fehr and Schmidt's (1999) model of inequality aversion and find that actual behavior fits remarkably well with these predictions in a quantitative sense, but there are also two contradictions to the model's predictions.

JEL Classification: C92, D70, H41

Keywords: Experimental economics, sequential play, step-level public good.

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1 Introduction

Public goods often have a step-level character, that is, the public good is provided only if some minimum threshold of contributions (or provision-point) is met. Examples include the building of a bridge or a dike. Also charities often have properties of step-level public goods (see the examples in Andreoni, 1998).

Our paper makes two contributions to the step-level public-goods literature. First, we analyze whether sequential contributions as opposed to simultaneous decisions improve public-good provision. Second, we analyze if an additional threshold which is not feasible in Nash equilibrium with standard preferences, where the public good is provided at a higher level, improves public-good provision.

The issue of sequential versus simultaneous decisions is subject of a substantial and growing literature. Following Hermalin (1998), researchers have analyzed “leading by example”. A first-mover may be better informed about the return to contributions allocated to the common endeavor, and may therefore give an example that is mimicked by the followers. As a result, sequential contributions to the public good are often superior to simultaneous decisions.¹ Erev and Rapoport (1990) were the first studying simultaneous vs. sequential moves in a step-level public good game.² To the best of our knowledge, we are the first studying a sequential threshold public good set-up with two players given the possibility of continuous contributions. At first, one would expect a sequential-move step-level public-good game seem superior to a simultaneous-move setting. A threshold public-good game is foremost a coordination game. With simultaneous moves, there are multiple equilibria and hence coordination failures may occur. Moreover, the public good is not provided in all equilibria. With sequential moves, there is a unique subgame perfect equilibrium in which the public good is provided. Hence, coordination and therefore public-good provision should be more frequent with sequential moves.

There is, however, an aspect of sequential decision making that may reduce its alleged superiority. With symmetric players, the first-mover is actually better off than the follower(s). In the unique subgame perfect equilibrium, the first-mover contributes the minimum so that a (best responding) follower just finds it worthwhile to contribute sufficiently high to meet the threshold. In other words, with selfish and rational players, the first-mover actually gives a *bad* example by

¹See Erev and Rapoport (1990), Potters et al. (2005, 2007), Güth et al. (2007), Gächter et al. (2010a, 2010b), Figuères et al. (2010). We review this literature below.

²In contrast to our set-up the authors analyze sequential step-level public good provision in groups of five players. Another difference is the application of the *Minimal Contribution Set*, i.e. players may either zero contribute or invest their whole endowment.

contributing *less* than the followers.³ In an experiment, this may reduce the alleged superiority of the sequential-move setting: players who try to exploit this first-mover advantage risk being “punished” by second-movers who do not best respond but contribute zero to the public good. If such behavior occurs frequently, the higher efficacy of the sequential-move game will not materialize.

Now consider our second extension, the step-level game with two thresholds. While multiple step-levels have been analyzed before (see for example Coller et al., 2001), we design our experiments such that the second threshold is *not* a Nash equilibrium with selfish and rational players. The second step-level is feasible, but given one player aims at the second threshold by contributing a high amount, the best response of a second player is to contribute low such that the first level only is met. With sequential moves, the second threshold introduces a trust-game aspect to the public-good game. Despite not being a Nash equilibrium, behaviorally, the existence of a second threshold might make it more likely that the *first* threshold will be met. Also, when players have Fehr and Schmidt (1999) preferences, the second threshold is a Nash equilibrium.

Our findings regarding the two main treatment variables are as follows. Sequential contribution decisions significantly improve public-good provision, even though first-movers frequently do contribute less than the followers and even though such behavior is regularly “punished”. Coordination and hence payoffs are higher whereas contributions are not higher with sequential moves. The existence of a second threshold causes significantly higher contributions but this does not result in higher public-good provision. To the contrary, payoffs are even significantly lower when there are two step-levels.

Our paper also introduces a methodological innovation. We make *quantitative* predictions for our experiment based on a fully calibrated Fehr and Schmidt’s (1999) model of inequality aversion. While Fehr and Schmidt’s (1999) model has frequently been used in the previous literature, the predictions are almost always of a qualitative nature (“if players are sufficiently inequality averse, *abc* is an equilibrium”). We will calibrate Fehr and Schmidt’s (1999) model on an existing (joint) distribution of the inequality parameters, and we will make exact quantitative predictions (“*v* percent of the first-movers will contribute *w*”; or “given a first-mover contribution of *x*, the public good will be provided in *y* percent of the cases”).⁴

We find that the calibrated Fehr and Schmidt (1999) model makes several remarkably accurate quantitative predictions but it also fails in two cases. The calibrated Fehr and Schmidt

³For some parameters, this also occurs in the Varian’s (1994) public-good game. See the experiment by Gächter et al. (2010a).

⁴Fehr, Krehelmer and Schmidt (2008) also provide an analysis based on a calibration of Fehr and Schmidt’s (1999) model. Their calibration is however based on a rather coarse two-type categorization (40 percent fair players and 60 percent standard players) and is not explicitly derived from existing data. See the discussion below.

(1999) model predicts second-mover behavior (given first-mover behavior) in the sequential variant extremely well. Specifically, it predicts accurately the frequency with which second-movers punish low-contributing first-movers by contributing zero. The prediction regarding the first-movers fails: first-movers should anticipate (or learn) that second-movers punish low contributions and thus always make the payoff-equalizing contribution; however, only slightly more than one third of them do so. The calibrated Fehr and Schmidt (1999) model also predicts well the case with simultaneous-move contributions where some players contribute whereas others do not. Finally, the model rather precisely predicts the share of first-movers who trust second-movers by making a high contribution in the two-threshold case. Here, the prediction regarding the second-movers fails who exploit first-mover trust significantly more frequently than predicted.

2 Experimental Design

In our experiments, there are two players, player 1 and player 2, who each have a money endowment $e = 10$. They can make a voluntary contribution, c_i , to the public good, where $0 \leq c_i \leq e$.

In half of our treatments, there is *one threshold* for the provision of the public good. If the sum of contributions is at least 12, this yields an additional payoff of 10 to both players. More formally, if x_i denotes player i 's monetary payoff, then

$$x_i = \begin{cases} e - c_i + 10 & \text{if } c_1 + c_2 \geq 12 \\ e - c_i & \text{if } c_1 + c_2 < 12 \end{cases}$$

The other treatments involve an additional *second threshold* of 18. If $c_1 + c_2 \geq 18$, both players receive an additional 15. That is, in these treatments, we have

$$x_i = \begin{cases} e - c_i + 15 & \text{if } 18 \leq c_1 + c_2 \\ e - c_i + 10 & \text{if } 12 \leq c_1 + c_2 < 18 \\ e - c_i & \text{if } c_1 + c_2 < 12 \end{cases}$$

Since $2e > 18$, both thresholds of the public good are feasible, but, due to $e < 12$, no player can meet the threshold on her own. Further, because $2 \cdot 10 > 12$ and $2 \cdot 15 > 18$, the provision of the public good at both provision points is collectively rational.

We have four treatments, labeled SIM_1, SIM_2, SEQ_1, and SEQ_2. The SIM labels refer to treatments where the two players make their decisions simultaneously whereas decisions are made sequentially (with player 1 moving first) in the SEQ treatments. The second treatment variables are the number of the thresholds (one or two). Table 1 summarizes our 2×2 treatments design.

		Order of moves	
		simultaneous	sequential
Step-levels	one	SIM_1	SEQ_1
	two	SIM_2	SEQ_2

Table 1: *Treatments*

Subjects play this game over 10 periods. In each period, subjects were endowed with 10 euros but only one period was paid at the end of the experiment. Subjects were randomly matched in groups of two players. In the SEQ treatments, also the roles of first and second-movers were random.

We have three independent sessions per treatment. The size of the sessions (matching groups) varied between 10 and 18 subjects. We control for session size in our data analysis below. The subject pool consists of students from the University of Frankfurt from various fields. In total, we had 160 participants who earned on average 11.3 euros. The experiment was programmed in z-Tree (Fischbacher, 2007).

3 Predictions

3.1 Assumptions

We now derive the one-shot equilibrium predictions for this public-good game. In addition to standard Nash predictions (selfish players who maximize their own monetary payoff), we will use Fehr and Schmidt’s (1999) model, henceforth F&S. In their model, players are concerned not only about their own material payoff but also about the difference between their own payoff and other players’ payoffs.

Assumption 1. *Players’ preferences can be represented by the utility function $U_i(x_i, x_j) = x_i - \alpha_i \max[x_j - x_i, 0] - \beta_i \max[x_i - x_j, 0]$, $x_i, x_j = 1, 2, i \neq j$.*

Here, x_i and x_j denote the monetary payoffs to players i and j , and α_i and β_i denote i ’s aversion towards disadvantageous inequality (envy) and advantageous inequality (greed), respectively. Standard preferences occur for $\alpha = \beta = 0$. Following F&S, we assume $0 \leq \beta_i < 1$.

Using the specific functional forms of the step-level public good game for x_i above, we can write the F&S utilities as a function of contributions $U_i(c_i, c_j)$ directly. For the treatments with one step-level, we obtain

$$U_i(c_i, c_j) = 10 - c_i + 10\chi_1 - \alpha_i \max[c_i - c_j, 0] - \beta_i \max[c_j - c_i, 0] \quad (1)$$

$c_i, c_j = 1, 2; i \neq j$ whereas, for the two-step-levels treatments, we get

$$U_i(c_i, c_j) = 10 - c_i + 10\chi_1 + 15\chi_2 - \alpha_i \max[c_i - c_j, 0] - \beta_i \max[c_j - c_i, 0]. \quad (2)$$

Here, the χ_k are indicator functions indicating whether a step level has been reached: $\chi_1 = 1$ iff $18 > c_1 + c_2 \geq 12$ and $\chi_2 = 1$ iff $c_1 + c_2 \geq 18$.

Using this model, we will make *quantitative* predictions. We fully calibrate the F&S model using the joint distribution of the α and β parameters observed in Blanco, Engelmann and Normann (2010). For each subject, they derive an α_i from rejection behavior in the ultimatum game and a β_i from a modified dictator game.⁵ The use of this joint distribution seems promising as it successfully predicts outcomes in several games (ultimatum game, sequential-move prisoner's dilemma, public-good game) which have a similar complexity as the present game (see Blanco, Engelmann and Normann 2010).

Assumption 2. *Players' inequality parameters are given by known joint α - β distribution in Table 2. This distribution is common knowledge.*

⁵While Fehr and Schmidt (1999) derive distributions for these parameters based on data from previous ultimatum-game experiments, here, we need the *joint* distribution of the parameters. Such a joint distribution of inequality-aversion parameters for the Fehr and Schmidt model was first elicited by Blanco, Engelmann and Normann (2010). Fehr, Krehmelmer and Schmidt (2008) make an assumption about the joint distribution; namely that there are 60% players with $\alpha = \beta = 0$ and 40% "fair" types with $\alpha = 2$ and $\beta = 0.6$.

Subject	α_i	β_i	Subject	α_i	β_i	Subject	α_i	β_i
1	0	0	22	0	0.875	42	4.5	0.775
2	0	0.025	23	0.026	0	43	0	0.775
3	0.026	0	24	0.409	0.175	44	1.5	0.025
4	0.026	0.175	25	2.833	0.475	45	2.833	0.575
5	0.409	0.175	26	0	0.975	46	0.088	0.625
6	0.409	0.525	27	0	0.625	47	0.269	0.775
7	0.409	0.125	28	0.167	0.825	48	0.409	0.175
8	0.409	0.675	29	0.409	0.625	49	0.611	0.725
9	0.611	0.675	30	0.409	0	50	0.269	0.525
10	0.611	0.275	31	0.409	0.175	51	0	0.525
11	0.611	0.575	32	0.611	0.175	52	0	0.725
12	0.611	0.525	33	1.5	0.375	53	0.269	1
13	1.5	0.525	34	4.5	0.025	54	0.409	0.525
14	1.5	0.975	35	0	0.525	55	0.929	0.025
15	1.5	0.725	36	0.026	0.725	56	1.5	1
16	4.5	0.425	37	0.409	0.325	57	2.833	0.675
17	4.5	0.875	38	0.611	0.375	58	4.5	0.525
18	0.929	0.475	39	0.611	0.725	59	4.5	0
19	0.269	0.475	40	0.611	0.025	60	4.5	0
20	1.5	0.825	41	0.929	0.875	61	4.5	0.625
21	2.833	0.275						

Table 2: Blanco et al.'s (2010) joint α and β distribution

3.2 Seq_1

We start with the *sequential-move variant with one threshold* (SEQ_1). In that treatment, a second-mover (S) with standard preferences will best respond to the first-mover's (F) contribution, c_F , by choosing zero if $c_F < 2$ and by contributing $12 - c_F$ if $c_F \geq 2$. Anticipating this, the first-mover will choose her payoff maximizing contribution, which is $c_F = 2$.

Next consider players who are consistent with Assumptions 1 and 2. Second-movers with F&S preferences might choose $c_S = 0$ even if $c_F \geq 2$ as their utility maximizing action if the payoff inequality implied by c_F becomes too big. For $c_F \in [2, 6]$ and facing the decision between contributing $12 - c_F$ and $c_F = 0$, the second-mover either obtains $U_S(12 - c_F, c_F) = 8 + c_F -$

$\alpha_i(12 - 2c_F)$ or $U_S(0, c_F) = 10 - \beta_i c_F$. We find that $U_S(12 - c_F, c_F) > U_S(0, c_F)$ iff

$$c_F \geq \frac{2(1 + 6\alpha)}{1 + 2\alpha + \beta} \equiv \tilde{c}_F. \quad (3)$$

The \tilde{c}_F in (3) is a minimum acceptable first-mover contribution for a given set of individual inequality parameters. Any contribution as least as high as \tilde{c}_F will be met by $c_S = 12 - c_F$ and will result in the public good being provided. Any contribution lower than this threshold will be met by $c_S = 0$. Intuitively, \tilde{c}_F is increasing in α and decreasing in β .

Based on our Assumption 2 (the joint distribution of the α and β parameters observed in Blanco, Engelmann and Normann, 2010), we now predict the frequencies of public-good provision as a function of c_F . For each player in that data set (see Table 2), we determine the \tilde{c}_F as in (3). For subject 1 with $\alpha = \beta = 0$, for example, we obtain $\tilde{c}_F = 2$ as the minimum acceptable first-mover contribution, whereas subject 58 with $\alpha = 4.5$ and $\beta = 0.525$ has $\tilde{c}_F = 5.32$ as the minimum acceptable first-mover contribution and will thus only accept $c_F = 6$. This allows us to predict how many players in *our* experiment will (not) provide the public as a function of c_F .

Table 3 shows the results of this calibration. In contrast to the game of players with standard preferences, the likelihood of public-good provision is strictly below 100 percent as long as $c_F < 6$. Table 3 also reveals that the expected monetary payoff of a risk-neutral first-mover monotonically increases in c_F and is maximized for $c_F = 6$.⁶ Players with a F&S utility function will a fortiori choose $c_F = 6$ as it, in addition, minimizes the payoff inequality.

Second-mover contribution	First-mover contribution				
	$c_{FM} = 2$	$c_{FM} = 3$	$c_{FM} = 4$	$c_{FM} = 5$	$c_{FM} = 6$
$c_{SM} = 12 - c_{FM}$ (PG level 1 provided)	21.3%	37.7%	67.2%	83.6%	100%
$c_{SM} = 0$ (PG not provided)	78.7%	62.3%	32.8%	16.4%	0%
expected first-mover payoff	10.13	10.77	12.72	13.36	14.00

Table 3: Predicted second-mover responses conditional on first-mover choices and the resulting expected first-mover monetary payoff in SEQ_1 and SEQ_2

Thus we have

⁶The expected payoff from choosing $c_F = 0$ is 10; $c_F > 6$ results in a lower likelihood of public-good provision, lower payoffs, and greater payoff inequality. Thus a selfish first-mover will choose $c_F = 6$.

Proposition 1. For treatment SEQ_1, the standard model predicts $c_S = 0$ if $c_F < 2$, $c_S = 12 - c_F$ if $c_F \geq 2$ and $c_F = 2$. The calibrated F&S model predicts the frequencies of second-mover responses as in Table 3, and $c_{FM} = 6$ for the first-movers.

3.3 Seq_2

Now consider the *sequential-move variant with two thresholds* (SEQ_2). If the first-mover contributes $c_F \leq 6$, the analysis is as above. But in the two-level game, the first-mover may also choose her contribution in the range $c_F \in [8, 10]$ in order to make the second level feasible.

Players with standard preferences will not provide the public good at the second level in equilibrium. Given $c_F \in [8, 10]$, second-movers will respond with $c_S = 12 - c_F$ (yielding a monetary payoff of $8 + c_F$) but not with $c_S = 18 - c_F$ (which would yield only $7 + c_F$). By backward induction, first-movers will not choose $c_F \in [8, 10]$ but $c_F = 2$, as in the game with one step-level. The second threshold is irrelevant with standard preferences.

Second-mover contribution	First-mover contribution		
	$c_{FM} = 8$	$c_{FM} = 9$	$c_{FM} = 10$
$c_{SM} = 18 - c_{FM}$ (PG level 2 provided)	39.3%	80.3%	80.3%
$c_{SM} = 12 - c_{FM}$ (PG level 1 provided)	60.7%	19.7%	19.7%
$c_{SM} = 0$ (PG not provided)	0.0%	0.0%	0.0%
expected first-mover payoff	13.97	15.02	14.02

Table 4: Predicted second-mover responses conditional on first-mover choices between 8 and 10 and expected first-mover monetary payoff in SEQ_2

Now consider F&S players and begin with the second-movers. With $c_F \in [8, 10]$, the second-mover may choose $c_{SM} = 18 - c_{FM}$, $c_{SM} = 12 - c_{FM}$ or $c_{SM} = 0$. Since $U_S(12 - c_F, 0) > U_S(0, c_F)$ for $c_F \in [8, 10]$, we can restrict the second-mover choices to $c_{SM} = 18 - c_{FM}$ and $c_{SM} = 12 - c_{FM}$. First suppose $c_F = 8$. If the second-mover chooses $c_S = 18 - c_F$, we have $\chi_2 = 1$ and thus

$U_F(10, 8) = 15 - 2\alpha_i$. If she chooses $c_S = 12 - c_F$, we have $\chi_1 = 1$ and $U_F(4, 8) = 16 - 4\beta_i$. We obtain $U_S(10, 8) < U_S(4, 8)$ iff $1 - 4\beta + 2\alpha > 0$. This condition holds for for 60.7 percent of the subjects. That is, if $c_F = 8$, the public good will be provided at level one with 60.7 percent probability and with 39.3 percent probability at level two. Then consider $c_F = 9$. If $c_S = 18 - c_F$, we obtain $U_F(9, 9) = 16$, whereas for $c_S = 12 - c_F$ we get $U_F(4, 8) = 17 - 6\beta_i$. We find that $16 < 17 - 6\beta_i$ iff $1 - 6\beta > 0$. In the data of Blanco, Engelmann and Normann (2010), 19.7 percent of the subjects meet this condition. That is, if $c_F = 9$, the public good will be provided at level one (two) with 19.7 (80.3) percent probability. Finally, the case $c_F = 10$ turns out to be identical regarding the second-movers' incentive. That is, $c_F = 9$ and $c_F = 10$ are equally likely to be "exploited" by the second-mover, and the predicted frequencies of public good provision are hence the same. Table 4 summarizes the additional predictions in SEQ_2.

Consider next the first-movers. $c_{FM} = 10$ will never be chosen by first-movers because $c_F = 9$ triggers to the same second-mover response as $c_F = 10$ (in terms of public good provision) but $c_F = 9$ yields a higher expected payoff and higher F&S utility than $c_F = 10$. As for the choice between $c_F = 8$ or $c_F = 9$, we find that $c_F = 8$ yields a lower expected monetary payoff than $c_F = 6$ (see Table 4) and accordingly an even lower F&S utility. Hence, a risk neutral first-mover will never choose $c_F = 8$. The remaining possibilities are that first-movers will either choose $c_F = 6$ or $c_F = 9$. Contributing $c_F = 6$ yields an expected utility of 14 and $c_F = 9$ gives an expected utility of $15.015 - 1.182\alpha$. Now $15.015 - 1.182\alpha > 14$ iff $\alpha < 0.859$. This is predicted to hold for 36 percent of the Blanco, Engelmann and Normann (2010) subjects.

Proposition 2. *For treatment SEQ_2, the standard model makes the same predictions as for SIM_1. The calibrated F&S model predicts the frequencies of second-mover responses as in Tables 3 and 4, and that 64% of all first-movers choose $c_{FM} = 6$ and 36% choose $c_{FM} = 9$.*

Taking second- and first-mover predictions together, we finally derive the prediction for the frequencies of public-good provision. We expect the public good to be provided at step-level 1 with a frequency of $0.64 + 0.36 \cdot 0.197 = 0.711$ and at step-level 2 in the rest of the cases.

3.4 Sim_1

With simultaneous moves, there are multiple equilibria both in the standard model and in the F&S model. With standard preferences, both players contributing nothing and all allocations where $c_1 + c_2 = 12$ are the pure-strategy equilibria.⁷ Perhaps somewhat surprisingly, all of these equilibria

⁷There are also numerous mixed-strategy equilibria.

are also Nash equilibria with calibrated F& S preferences except for those where $(c_1 = 2, c_2 = 10)$ and $(c_1 = 10, c_2 = 2)$. (Proof available upon request.)

We believe that it is unlikely that entirely symmetric players will coordinate on asymmetric equilibria and we therefore focus on symmetric pure-strategy equilibria $c_i = c_j = 0$ and $c_i = c_j = 6$. For $c_i = 6$ to be a best reply with standard preferences requires that player j chooses $c_j = 6$ with at least 60 percent. (This implies that there exists a symmetric mixed-strategy equilibrium in which both players contribute $c_i = 0$ with 40 percent probability and $c_i = 6$ otherwise with standard preferences.)

With the calibrated F&S model, the symmetric pure strategy equilibria $c_i = c_j = 0$ and $c_i = c_j = 6$ are the same but the best response correspondence changes both quantitatively and qualitatively. Here, player j must choose $c_i = 6$ with at least 64 percent. Hence, there is a small shift compared to the standard case and, all else equal, coordination on $(c_1 = 6, c_2 = 6)$ is actually less likely to be met than with standard preferences. There is, however, also a qualitative difference to the standard case. With the calibrated F&S model, it is not the case that all players have the same best response if there are more or less than 64 percent players with $c_i = 6$ in the population. Learning will be slower and the shape of the best response correspondence differs from the standard case (see below).

Proposition 3. *For treatment SIM_1, there are multiple equilibria both with standard and F&S preferences. The symmetric pure-strategy Nash equilibria are $c_i = c_j = 0$ and $c_i = c_j = 6$. For $c_i = 6$ to be a best reply with standard preferences requires that player j chooses $c_j = 6$ with at least 60 percent; or 64 percent in the case of F&S preferences.*

3.5 Sim_2

We now turn to the variant with *simultaneous-move game with two thresholds* (SIM_2). As argued above for SEQ_2, meeting the second threshold is not a Nash equilibrium with standard preferences. As the equilibria derived above for SIM_1 are unaffected by the introduction of the second threshold; with standard preferences, SIM_2 has the same Nash equilibria as SIM_1.

We look for a Bayesian Nash equilibrium of players with F&S utilities where the second level public good is provided. A Bayesian Nash Equilibrium is a combination of type-dependent strategies such that every player maximizes her expected utility, given her F&S type and the strategies of all other players. Suppose that some types choose $c = 9$. Above, we have seen that, given $c_i = 9$, 80.3 percent of all types will reply with $c_j = 9$ whereas the rest plays $c_j = 3$. Hence, there

cannot be a Bayesian Nash equilibrium where all types choose $c_i = 9$. We will therefore look for a Bayesian Nash equilibrium where p percent of all F&S types choose $c_i = 9$ whereas $1 - p$ choose $c_i = 3$.

The expected utility from playing $c = 9$ is $pU(9, 9) + (1 - p)U(9, 3) = 16p + (1 - p)(11 - 6\alpha)$, and the expected utility from playing $c = 3$ is $pU(3, 9) + (1 - p)U(3, 3) = p(17 - 6\beta) + (1 - p)7$. Contributing 9 yields a higher expected F&S utility than contributing 3 iff

$$p > \frac{6\alpha - 4}{6\alpha + 6\beta - 5}.$$

For F&S players with, for example, $\alpha = \beta = 0$, this condition is never met; that is, selfish own utility maximizers will always choose $c = 3$. If p is sufficiently large, however, inequality averse players prefer $c = 9$. In the Blanco, Engelmann and Normann (2010) data, we find that for $p = 0.72$ exactly 72 percent of the players have $pU(9, 9) + (1 - p)U(9, 3) > pU(3, 9) + (1 - p)U(3, 3)$ whereas for 28 percent the inequality is reversed. Thus these strategies constitute a Bayesian Nash equilibrium. It remains to check, though, whether it pays to deviate to any contribution other than 9 or 3. The only possible deviation is to contribute $c = 0$ since any other contribution is not a F&S best reply to either 9 or 3. Contributing $c = 0$ yields an expected F&S utility of $10 - 3\beta - 0.72 \cdot 6\beta$. But the equilibrium action $c = 3$ yields $0.72(17 - 6\beta) + (0.28)7$ which is strictly larger for all $\beta \in [0, 1]$.

Thus we have established

Proposition 4. *Treatment SIM_2 has the same Bayesian Nash equilibria as SIM_1. With standard preferences, there are no additional equilibria. With the calibrated F&S model, 72 percent of the F&S types choosing $c = 9$ and the rest $c = 3$ is a Bayesian Nash equilibrium.*

3.6 Hypotheses

Based on Propositions 1 to 4, we will now derive two hypotheses regarding the impact of our two treatment variables. We will return to the propositions and the performance of the F&S model below.

Comparing the predicted public-good provision in SIM vs. SEQ, we note that there are multiple equilibria in the SIM treatments and that the public good is not provided in all equilibria. By contrast, in the SEQ treatments, the equilibrium is unique and the public good is provided (at least at level one) in the unique equilibrium. This holds for both the one and the two-threshold case.

Hypothesis 1. *The public good will be provided more frequently in the SEQ treatments compared to SIM.*

Note that this hypothesis does not depend on assuming that players have F&S preferences. The F&S model makes the point that the $c_F = 2$ predicting with standard preferences in the SEQ treatments will be punished frequently by the second-movers, but it also predicts that this case will not arise because first-movers anticipate this. Our second hypothesis does depend on assuming F&S preferences.

Propositions 1 to 4 show that public-good provision can be improved if there is the second threshold. In the SEQ treatments, the public good will always be provided at level one but in 29% of the cases also at step-level two. The case for improved public good provision in the SIM treatments is as follows. There are multiple equilibria in the SIM treatments anyway but there exist an equilibrium in which the second level is met with positive probability. For both SEQ_2 and SIM_2, we note that even if one player attempts to reach the second level by choosing e.g. $c_i = 9$ and the other player exploits this with $c_j = 3$, this does not harm payoffs as the first level of the public good is still provided. Thus the two-level treatments should be weakly superior.

Hypothesis 2. *The public good will be provided more frequently in the treatments with two threshold compared to one-threshold treatments.*

4 Main treatment effects

We present our results in two parts. Section 4 presents tests of Hypotheses 1 and 2. In addition to public good provision, we will also analyze contributions and payoffs (or efficiency). The next section presents a more detailed analysis of the predictive power of the calibrated F&S model.

When we apply regressions analysis, we use Generalized Linear Latent and Mixed Models (gllamm; see Rabe-Hesketh and Skrondal, 2005) regressions, taking possible dependence of observations at the level of a (randomly matched) group and at the individual level into account. As dependent variables we use *sequential* (a dummy which is equal to one if the move order is sequential), *twolevel* (a dummy which is equal to one if there are two levels), *seq2* (an interaction term for the sequential treatment with two levels), furthermore we control for *period* and the *sessionsize*.

We typically report three regressions. Regression (1) reports the impact of the treatment variables *sequential* and *twolevel* only. Regressions (2) includes the interaction *seq2*, and (3) adds *period* and *sessionsize*.

4.1 Overview

We start with a summary statistics of our four treatments in Table 5. It shows public good provision contributions, frequency of coordination, and the resulting payoffs. Note in our treatments with two threshold levels we also count the cases where the second level has been achieved as successful provision of *PG level 1*.

As can be seen, public good provision at the first level is most effective in the treatments with sequential-move order. *PG level 1* is provided most frequently (85.56%) with the sequential-move order and two thresholds and thus *PG level 1* provision is also more effective in SEQ_2 compared to SEQ_1 where only 75.24% subjects manage to provide the public good. Only in 6% of SIM_2's cases is the public good provided at the second threshold level. However, the second threshold level does come out better with sequential-move order (16.67% of PG level 2 in SEQ_2). The second threshold level leads to higher contributions in the simultaneous as well as in the sequential treatment. We define successful coordination as cases without wasteful contributions (that is cases where $c_1 + c_2 \in \{0, 12\}$, or $c_1 + c_2 \in \{0, 12, 18\}$ in the two step-level cases). Coordination is best in the environment of sequential moves. Furthermore the sequential-move order also leads to higher payoffs compared to the simultaneous treatments.

Variable	Treatment			
	SIM_1	SIM_2	SEQ_1	SEQ_2
PG level 1 provided (in %)	64.29	59.00	75.24	85.56
PG level 2 provided (in %)	-	6.00	-	16.67
Contributions	5.22	5.99	4.96	6.07
	(2.23)	(2.88)	(2.36)	(2.57)
Coordination (in %)	49.05	17.00	77.62	81.11
Payoff	11.21	10.30	12.56	13.32
	(3.86)	(4.27)	(2.92)	(3.18)

Table 5: Summary statistics of our four treatments

A first look at the data in Table 5 thus suggest that we do find tentative support for Hypothesis 1. Regarding Hypothesis 2, the effect is ambiguous as ambiguous since the second level improves public-good provision (at level one) in the SEQ treatments but not in the SIM settings.

4.2 Public-good provision level 1

We begin with a probit regression regarding our main variables of interest, the provision of the public good at level 1. The regression shows that *sequential* is significant and therefore the sequential-move order improves the PG provision at the first threshold. This is support for Hypothesis 1. The implementation of a second threshold does not lead to a higher frequency of public good provision. The same is true for the sequential treatment with two thresholds. That is, we do not find support for Hypothesis 2 which predicts that the second threshold leads to more public good provision.

We find that the coefficient of *sessionsize* is negative and weakly significant. That is, sessions with a higher numbers of subjects exhibit lower public-good provision. This is consistent with findings in Botelho et al. (2009). Botelho et al. (2009) compare repeated settings with “random strangers” and “perfect strangers” matching protocols and find that the assumption that subjects treat Random Strangers designs as if they were one-shot experiments is false. Our results indicate that the session size and hence the likelihood of meeting a random stranger once more has an impact on cooperation. We note, however, that the coefficient of *sessionsize* is very small. (Recall that our sessions had a size between 10 and 18.)

	(1)	(2)	(3)
sequential	0.657*** (0.184)	0.390* (0.229)	0.395** (0.200)
twolevel	0.123 (0.183)	-0.137 (0.227)	-0.151 (0.199)
seq2		0.541 (0.330)	0.429 (0.297)
period			-0.00633 (0.0124)
sessionsize			-0.0643* (0.0346)
Constant	0.281* (0.154)	0.408** (0.160)	1.342*** (0.509)
Observations	1,600	1,600	1,600

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Gllamm probit regression: PG provision level 1

4.3 PG Provision level 2

Table 6 presents a gllamm probit regression of the frequency of PG provision of level 2. Again we use *sequential*, *period* and *sessionsize* as dependent variables but *twolevel* cannot be part of the analysis, of course. The table documents that *sequential* is again significant, that is, sequential-move contributions also stimulate the provision of the second level which is additional support for Hypothesis 1 (which postulates that public good provision will be more effective when a sequential move order is used). This result holds for the one threshold case as well for the two threshold case.

Furthermore, regression (2) reveals that *PG provision level 2* slightly decreases over time. The dummy *sessionsize* is not significant here.

	(1)	(2)
sequential	0.638** (0.300)	0.550** (0.277)
period		-0.0466* (0.0241)
sessionsize		-0.0669 (0.0507)
Constant	-1.773*** (0.230)	-0.630 (0.716)
Observations	759	759

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Gllamm regression: PG provision level 2

4.4 Contributions

The following table shows a linear regression on players' contributions. Again we control for the impacts of the sequential move order and the second threshold. We see that contributions are *not* significantly influenced by the order of moves. Interestingly, adding the second threshold leads to significant higher contributions. The interaction of a sequential move order and two levels does not lead to further increased contributions.

Over time, contributions get weakly smaller. *sessionsize* is significant, that is, in sessions with more participants contributions are slightly lower.

	(1)	(2)	(3)
sequential	-0.00397 (0.254)	-0.126 (0.304)	-0.0959 (0.315)
twolevel	1.202*** (0.257)	0.904** (0.424)	0.684*** (0.244)
seq2		0.446 (0.528)	0.390 (0.436)
period			-0.0330* (0.0175)
sessionsize			-0.135*** (0.0434)
Constant	5.039*** (0.169)	5.076*** (0.174)	7.151*** (0.639)
Observations	1,600	1,600	1,600

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Gllamm regression: Contribution

4.5 Payoffs

Next, we present the results of a linear regression analysis of subjects' payoffs. Firstly, the table shows that the sequential contribution mechanism significantly improves subjects' payoffs. This is due to the fact that public-good provision is improved by the sequential-move order.

The second step-level significantly reduces the payoffs. This can be explained by the fact that, on the one hand, two thresholds increase contributions but, on the other hand, the second level is rarely actually achieved. When we add the interaction *seq2*, we find that it significantly boosts subjects' payoff by 1.4 compared to the baseline SIM_1. The difference between SEQ_1 and SEQ_2 is, however, not significant as follows from a Wald test ($p = 0.22$). This emphasizes the overall negative impact of the second threshold on payoffs. Indeed, payoffs are worst in SIM_2.

Furthermore the size of the sessions is weakly significant, but again the coefficient is very small ($< .12$). The time trend is insignificant here.

	(1)	(2)	(3)
sequential	2.140*** (0.379)	1.390*** (0.446)	1.389*** (0.386)
twolevel	-0.0103 (0.393)	-0.867** (0.439)	-0.898** (0.392)
seq2		1.595*** (0.618)	1.404** (0.565)
period			-0.00250 (0.0310)
sessionsize			-0.115* (0.0671)
Constant	10.84*** (0.254)	11.21*** (0.323)	12.83*** (0.99)
Observations	1,600	1,600	1,600

*** p<0.01, ** p<0.05, * p<0.1

Table 9: Gllamm regression: Payoffs

The payoff variable is the variable a social planner is ultimately interested in. Payoffs reflect the combined effect of contributions, public-good provision and coordination. The above regression confirms that the payoff differences reported in our summary statistics are significant. Specifically, it follows that SEQ_2 has the highest payoffs, followed by SEQ_1 and SIM_1, and SIM_2 has the lowest payoffs. Note that this is precisely the ranking of payoffs which are implied by our two Hypotheses.

5 The predictive power of the calibrated F&S model

We now discuss the quantitative predictions of the F&S model in more detail. While our Hypothesis 2 was based on the F&S model and largely failed, we will see that some of the models predictions materialize rather well.

We begin with Proposition 1. The F&S model predicts the second-mover responses amazingly well. Figure 1 contrasts the predictions made in Table 3 to the observed frequencies. Using binomial tests, we cannot reject that predicted and observed frequencies are the same (all $p > 0.5$).⁸ We

⁸For $c_F = 6$ we cannot apply a binomial test because the predicted frequency is 100 percent. regarding $c_F = 2$, we only have two observations so we cannot test either (in one case the PG was provided so the provision).

are confident that both the exact quantitative prediction and the confirmation of the hypothesis in the data constitute a significant finding in experimental economics.

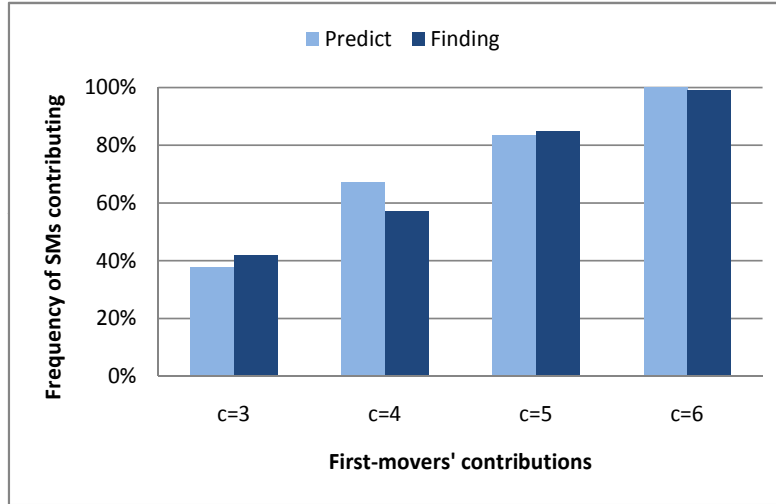


Figure 1: Predicted frequencies (based on the calibrated F&S model) and observed frequencies of second-movers contributing such that the PG at level 1 is provided.

Part of Proposition 1 is that first-movers should choose $c_F = 6$ in order to maximize payoffs and F&S utilities. This is clearly not the case as $c_F = 6$ is chosen only in 37.1 percent of the cases. While this rejects the F&S prediction, we note that similar observations have been made before. For standard ultimatum-game experiments, it can be argued that offering the equal split may be payoff maximizing (assuming risk neutrality), but about half the proposers offer less than the equal split.⁹ Huck, Müller and Normann (2001) show that, in quantity-setting duopoly, Stackelberg followers are inequality averse but the Stackelberg leaders still choose too high an output (to be precise, the Stackelberg leader output is below the standard prediction but above what would be payoff maximizing). Risk-loving behavior can explain the first-mover behavior.

Figure 2 is a bubble plot of first- and second-movers in SEQ_1. The modal outcome is (6, 6) as predicted, and many observations are on the Pareto frontier where $c_F + c_S = 12$. However, one also clearly identifies the “punishing” second-movers on the vertical axis where $c_S = 0$.

⁹In Blanco, Engelmann and Normann (2010), offering the equal split is actually payoff maximizing, but that ultimatum game was done with the strategy method which typically induces higher rejection rates.

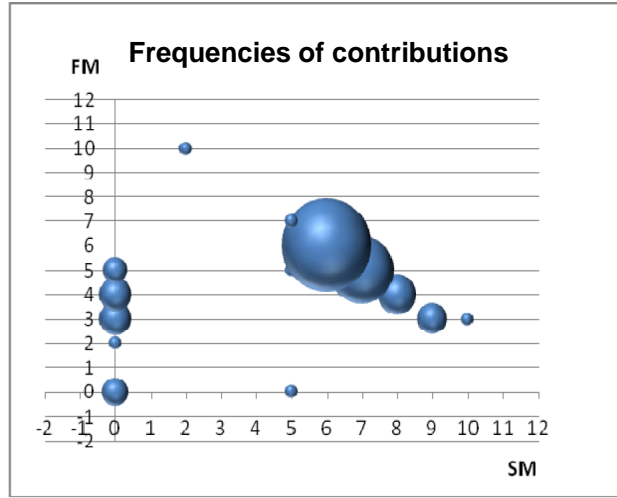


Figure 2: Bubble plot of first- and second-movers in SEQ.1. Bubbles increase with frequency of outcome of the data

For the first-movers in SEQ.2, Proposition 2 predicts that 36 percent contribute $c_F = 9$ and 64 percent should choose $c_F = 6$. In our data, 36.7 percent of the first-movers choose 9—which seems a remarkable confirmation of the prediction. The remaining 63.3 percent choose $c_F \in [2, 6]$. While we do not find that 64 percent choose $c_F = 6$, this only restates the previous finding that first-movers do not always choose the risk-neutral payoff maximizing action.

Intriguingly, the second-mover prediction of Proposition 2 fails (whereas it was the first-mover prediction of Proposition 1 that failed). The first-mover in the two-level case is in a trust-game like situation. If she chooses $c_F = 9$, she can be exploited by second-movers. While the calibrated F&S model predicts that more than 80.3 percent of the second-movers will be trustworthy, it turns out only 50.9 are. Predicted and observed share differ significantly (binomial test, $p < 0.05$). The failure of the theory seems surprising since the cost of being not trustworthy are higher here: second-movers gain only one additional euro by exploiting the first-mover, but this costs the first-mover five euros.

We finally turn to Proposition 3, the SIM.1 case. In SIM.1, we observe that in 81.4 percent of the cases subjects choose $c = 6$ and in 13.8 of the cases they choose $c = 0$. Hence, both the standard model and the calibrated F&S model would predict that play converges to the pure-strategy equilibrium where both players choose $c = 6$. This is, however, not the case. There is no positive time trend, and some players persistently choose $c = 0$. Why do subjects not best respond?

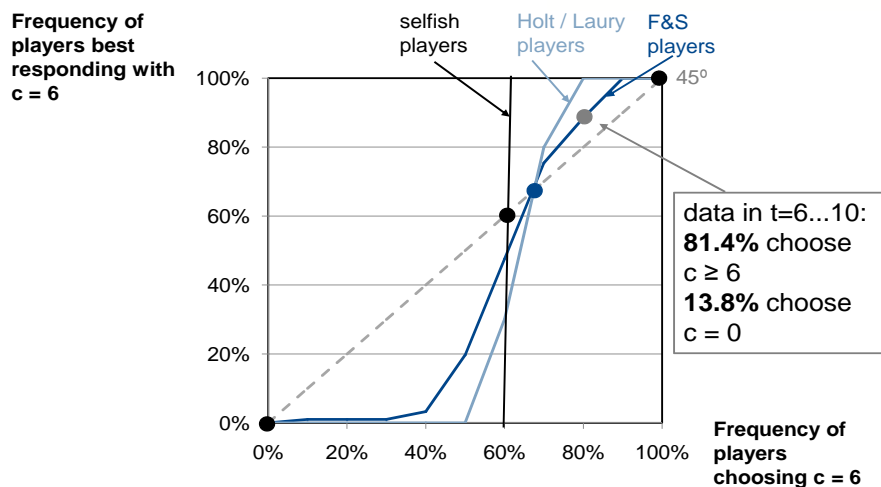


Figure 3: Best-reply correspondences for standard players, F&S players and Holt-Laury players in Sim_1.

Figure 3 illustrates what might be going on. It shows the best-reply correspondences for standard selfish players, for F&S players and also for players with standard preferences but with a degree of risk aversion according to the findings in Holt and Laury (2002). With selfish and rational player, the best reply correspondence has a “bang-bang” property. If the belief is that player j chooses $c_i = 6$ less than 60 percent, *all* players will best respond with $c_i = 0$, and vice versa for a belief of more than 60 percent. With the calibrated F&S model, this is not the case. For beliefs between (roughly) 40 and 80 percent, the best replies of the various F&S types differ. For example, given a belief that 70 percent of all players choose $c_i = 6$, only 75 percent of the players will best respond with $c_i = 6$ where 25 percent still choose $c_i = 0$.

As mentioned in Proposition 3, the share of players choosing $c_F = 6$ required such that $c_F = 6$ is a best reply is slightly larger with F&S players. Inequality aversion has an effect similar, in fact a stronger effect, than risk aversion (on average, players in Holt and Laury are slightly risk averse). We also see that the best replies differ from the case with standard preferences. Around the mixed-strategy equilibrium, the best replies are not vertical but somewhat “flat”, implying that not all players will best reply once the fixed point of the mixed strategy is exceeded. We believe that this is what we see in the data.

6 Conclusion

We analyze the provision of a step-level public good in an experiment. Specifically, we investigate how the order of moves (simultaneous vs. sequential) and the introduction of a second step-level (which is not feasible in standard Nash equilibrium) affects public-good provision. We find that the sequential-move game yields more frequent provision of the public good and higher payoffs. An additional step-level does lead to higher contributions but the effect on public-good provision is ambiguous and it lowers payoffs.

Based on the existing experimental data of Blanco, Engelmann and Normann (2010), we fully calibrate Fehr and Schmidt's (1999) model of inequality aversion to make *ex ante* predictions. We find that actual behavior fits quantitatively well with these predictions. Specifically, the F&S model predicts the second-mover responses amazingly well. While the predictive power on first-mover behavior is less impressive, similar findings have been observed before in other sequential games. The calibrated Fehr and Schmidt (1999) model also predicts behavior well in the sequential treatment with two step-levels, and in the simultaneous-move case with one level.

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Instructions to the experiment SEQ_2

Welcome to our experiment. By taking part in this experiment, you have the possibility to earn money. The amount you earn will depend on your decisions and it will also depend on the decisions of another participant, so please follow these instructions carefully. It is particularly important that you do not talk to any of the other participants until the experiment is over. Furthermore, please switch off your mobile phone. If you have a question, please raise your hand; we will come to your desk and answer it privately.

The experiment consists of exactly 10 rounds. At the end of the ten rounds, one of the ten rounds will be randomly selected. Your payoff in cash at the end will be the income you earned in this randomly selected round. There is an even number of participants in this room. At the beginning of each round, we will randomly match you with another participant. This may be a different participant from round to round. Please note that we will not inform you about the participant you are matched with.

Each round consists of two consecutive parts. In each part, exactly one participant makes a decision. Either you decide first or the other participant you are matched with does. The second decision is always the decision of the participant who did not make the first decision. At the beginning of each round, the computer randomly determines the participant who has to decide first. How you will earn your income is explained below.

The experiment

In the beginning of every round, you will be given an endowment of 10 Euros. You will have to decide about how to divide the 10 Euros into two possible projects.

One of the two projects is a **private project**. You are the only person who can contribute to this project. The other project is a **joint project** between you and the person you are matched with.

Every Euro you contribute to the private project will pay you one additional Euro at the end of the round. The joint project pays only if the sum of contributions to this project is **at least 12 Euros**. If this target is met, both you and the participant you are matched with will get a bonus payment of 10 Euros each at the end of the round. If the sum of contributions was **at least of 18 Euros**, you and the participant you are

matched with will receive a bonus payment of 15 Euros. Hence your income in each round is the sum of Euros contributed to the private project plus, potentially, the bonus payment of the joint project. Again, at the end of the ten rounds, we randomly select one of the ten rounds. Your income in this randomly selected round determines your payment at the end of the experiment.

To make sure that everybody understands how their earnings are determined, we will provide you with examples and additional control questions. Please take note that the contributions in Euro in these examples and control questions are entirely arbitrary and for demonstration purposes only. In the actual experiment, the payoffs will depend on the participants' actual decisions.

Example 1: You have to decide in part one of the round and you contribute 5 Euros to the joint project. Thus 5 Euros remain in the private project. The participant you are matched with is informed about your decision and contributes 7 Euros in the joint project thus 3 Euros remain in her private project. Thus there are 12 Euros in the joint project. This leads to a bonus payment of 10 Euros to both you and the person you are matched with. At the end of the round you receive 5 Euros from your private project plus the bonus payment of 10 Euros. Thus you altogether earn 15 Euros. The person you are matched with receives 3 Euros from her private project plus the bonus payment of 10 Euros. Thus she altogether earns a payoff of 13 Euros at the end of the round.

Example 2: You have to decide in part one of the round and you contribute 9 Euros to the joint project. Thus 1 Euro remains in the private project. The participant you are matched with is informed about your decision and contributes 9 Euros in the joint project thus 1 Euro remains in her private project. Thus there are 18 Euros in the joint project. This leads to a bonus payment of 15 Euros to both you and the person you are matched with. At the end of the round you receive 1 Euro from your private project plus the bonus payment of 15 Euros. Thus you altogether earn 16 Euros. The person you are matched with receives 1 Euro from her private project plus the bonus payment of 15 Euros. Thus she altogether earns a payoff of 16 Euros at the end of the round.

Example 3: Your matched participant has to decide in part one of the round. She contributes 6 Euros in the joint project thus 4 Euros remain in her private project. You have to decide in part two of the round. You are then informed about your matched participant's decision. You contribute 3 Euros to the joint project. Thus 7 Euros remain in your private project. Thus there

are 9 Euros in the joint project. This will not lead to a bonus payment due to the fact that the sum of contributions to the project is less than 12 Euros. At the end of the round you receive 7 Euros from your private project without an additional bonus payment. Thus you altogether earn 7 Euros. The person you are matched with receives 4 Euros from her private project without an additional bonus payment. Thus she altogether earns 4 Euros at the end of the round.

Control questions: Before we continue with the experiment instructions, we want to make sure that everybody understands how payoffs can be earned. Please answer the questions below. Please raise your hand if you have a question. After some minutes we will check your answers.

1.)

Assume we randomly determine you to decide in the second part of the round. You are first informed that your matched participant has contributed 8 Euros in the joint project.

a.) Assume you contribute 4 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

b.) Assume you contribute 2 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

2.)

Assume we randomly determine you to decide in the second part of the round. You are now being informed that your matched participant has contributed 9 Euros in the joint project.

a.) Assume you contribute 9 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

b.) Assume you contribute 8 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

3.)

Assume we randomly determine you to decide in the first part of the round. You contribute 3 Euros to the joint project in the first part of the round. Your matched participant is then informed about your decision.

a.) Your matched participant contributes 9 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

b.) Your matched participant contributes 0 Euros to the joint project

1. What is the profit from your private project? _____
2. What is the profit from your joint project? _____
3. What is your entire income at the end of the round? _____

4. What is your matched participant's profit from her private project? _____
5. What is your matched participant's bonus payment from the joint project? _____
6. What is your matched participant's entire income at the end of the round? _____

How you will make your decisions

At the beginning of each round, you have to decide about the number of Euros you want to contribute to the joint project. You will do this by entering your chosen number. You have the possibility to type in any integer number between 0 and 10. Note that you and the participant you are matched with decide at the same time and independently of each other.

After the decisions have been made, both participants will be given an information screen at the end of the round. This information screen will show the participants the individually chosen contributions to the joint project in that round. Both participants get information about their individual returns from their private projects. Furthermore, the amount of the bonus payment will be displayed. Additionally, both participants are informed about their individual total payoff in that round.

Beginning the experiment

Please take a look at your computer screen and make your decision. If you have a question at any time, please raise your hand we will come to your desk to answer it.