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# Going beyond suffering in public goods games when low contributions are inefficient: Experimenting with two institutions.

Daniela Di Cagno\* Werner Güth† Francesca Marazzi‡ Luca Panaccione§

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## Abstract

We analyze a public goods game with linearly increasing marginal returns to contributions, leading to a non-monotonic group payoff. By allowing the incentive to freeride to persist at all contribution levels, we preserve the usual social dilemma of voluntary public goods provision. We compare two conditions in which both let participants face the voluntary contribution task over a finite number of rounds: one implements it as a static game (Baseline condition), and the other implements it as a dynamic game with four successive stages of simultaneous contribution choices within each round (Milestone condition). Our data show that cooperation in the Baseline condition is rare and mostly limited to the first few rounds. The evidence for the Milestone condition is much more encouraging: contributions beyond suffering are substantial and fairly stable across rounds, although full contributions remain rare. This evidence suggests that the Milestone protocol is a promising institutional device for enhancing voluntary cooperation.

**Keywords:** Experiments, public goods, increasing marginal incentives to contribute, freeriding

**JEL Classification:** C72, C92, H41

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# 1 Introduction

In prominent real-world contexts, cooperative behavior yields net benefits only when voluntary contributions reach sufficiently high levels: although low contributions may reduce aggregate payoffs compared to freeriding, higher contributions can compensate for these losses, ultimately making widespread cooperation more efficient.

Consider, for example, the much-needed green transition. Economic and social efforts to move toward a low-carbon economy become more effective as more countries invest in the development and deployment of advanced technologies. In such cases, the benefits of increasing returns to specialization and learning by doing can offset the substantial costs associated with substituting exhaustible resources—costs that include capital stock replacement, workforce retraining, and adjustments in domestic and international trade patterns.<sup>1</sup> Moreover, reducing global greenhouse gas emissions is a collective action problem: while the burdens of the transition are largely national, the benefits are global. Even if the gross benefits of the transition are positive at low levels of investment and increase with scale, the net benefits may remain negative unless international investment reaches a critical mass.

To experimentally study voluntary cooperation under these conditions, we introduce a novel public goods framework characterized by linearly increasing marginal returns to contributions, leading to a non-monotonic group payoff: the marginal return to low total contributions falls below the marginal cost of contributing, thereby reducing the group payoff relative to general freeriding.<sup>2</sup> However, the return increases with total contributions and eventually exceeds the cost of contributing. This dynamic allows the initial losses to be overcompensated if contributions are high enough, and the group to reach its maximum payoff if each group member contributes fully. However, by allowing the incentive to freeride to persist at all contribution levels, the framework preserves the usual social dilemma of voluntary public goods provision.

Our setup increases the uncertainty faced by participants compared to the usual linear public goods game.<sup>3</sup> Unlike that game, the marginal per capita return (MPCR) varies with aggregate contributions. This means that participants are uncertain about the return to their own contribution, although it is always less than their marginal cost. Furthermore, it is characterized by general freeriding as a local maximum of the group payoff. Therefore, participants

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<sup>1</sup>See, e.g., Favas (2023).

<sup>2</sup>Our public goods game shares some features with Dorsey (1992), who however uses it with rather different research purposes.

<sup>3</sup>See, e.g., Davis and Holt (1993), Ledyard (1995), and Chaudhuri (2011) for surveys.

are uncertain whether the group will “go beyond suffering” to potentially reach its maximum payoff. Regarding the latter feature, however, our design provides a simpler setup to analyze the effect of inefficient low contributions compared to the threshold public goods game with no refund.<sup>4</sup> In fact, we do not need to consider features such as (no) refunds and (no) rebates, which make the experimental design more complex. Furthermore, our setup with always positive and smoothly increasing marginal returns to contributions avoids the coordination problems due to the multiplicity of Nash equilibria typical of threshold games.

In this paper, we experimentally compare two conditions which both let participants face the voluntary contribution task over a finite number of rounds: one implements it as a static game (hereafter, the Baseline condition), and the other implements it as a dynamic game with four successive stages of simultaneous contribution choices within each round (hereafter, the Milestone condition). In the Baseline condition, participants independently choose in each round how much of their endowment to contribute. In the Milestone condition, participants make an irrevocable decision at each stage whether to contribute a quarter of their endowment or not. Thus, participants have the same opportunities to contribute as in the Baseline condition, but they must build up cooperation gradually because missed increases on earlier stages cannot be made up. In both conditions, participants interact in groups of three, newly formed in each round,<sup>5</sup> and aware that they do not interact with the same two other participants in two consecutive rounds.

In the Baseline condition, the benchmark solution based on common(ly known) opportunism and dominance implies that participants should freeride in every round. In the Milestone condition, the same solution is obtained by backward induction. However, the dynamic interaction in this condition allows for reciprocity and reputation building in the sense of Kreps et al. (1982). The key idea here is to postulate that the other participants may be intrinsically motivated to cooperate but privately informed of their types. This allows opportunistic participants hide their opportunism by mimicking cooperative behavior. Therefore, in the initial stages, all participants cooperate and this leads to higher contributions on average.

Although the Milestone protocol offers more strategic possibilities, we believe it to be behaviorally simpler: one can gradually increase one’s total individual contribution, thus one’s contribution risk, in the light of what others have done so far. In the Baseline condition, instead,

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<sup>4</sup>See Croson and Marks, 2000, Croson, 2008, and Schram et al., 2008, for surveys

<sup>5</sup>Similarly to Duffy et al. (2007).

cooperative participants must solely rely on the trust in others, what renders high contributions quite risky. In the Milestone condition, a similar risk applies only to first-stage contributions, which, however, are limited to a quarter of the endowment. Therefore, we expect participants to generally contribute more in the Milestone than in the Baseline condition, and to more often succeed in going beyond suffering.

Our research focus is twofold: On the one hand, we want to investigate whether the contribution dynamics across rounds is governed by a watershed letting groups with initially low total contributions converge to general freeriding, while groups starting out beyond suffering increase voluntary cooperation and may even converge to full contribution. On the other hand, we want to test whether contributions in the Milestone condition are generally higher than in the Baseline condition, in line with related experimental evidence discussed in the next section.

Our data show that cooperation in the Baseline condition is rare and mostly limited to the first few rounds. Average contributions generally converge to freeriding, when participants become experienced. Only few groups (17.65%) manage to go beyond suffering. Instead, the evidence of the Milestone condition is much more encouraging: contribution levels beyond suffering are substantial and fairly stable across rounds, although full contributions remain rare. These results, which are consistent with the related experimental evidence discussed below, suggests that the contribution protocol used in the Milestone condition is a promising institutional device for enhancing voluntary cooperation, especially when participants face substantial risk when contributing.

The paper is organized as follows: Section 2 discusses some related literature; Section 3 describes our public goods game with increasing returns to contribution; Section 4 illustrates the experimental implementation and protocols; Section 5 discusses our main results; Section 6 concludes. Appendix A and Appendix B present additional material for equilibrium and data analysis, respectively. Appendix B and Appendix C provide English translations of the instructions for the Baseline and Milestone conditions, respectively.

## **2 On related public goods experiments**

Our public goods games, with the inefficiency of low total contributions and the smoothly increasing marginal returns to contributing, are clearly distinct from the public goods game

with constant MPCR and linearly increasing total payoff.<sup>6</sup>

They are also distinct from the threshold public goods game (see Croson and Marks, 2000, Croson, 2008, and Schram et al., 2008, for surveys) and the public goods game with interior Nash equilibria (see Laury and Holt, 2008, for a survey), although some features are reminiscent of them. In particular, low total contributions reduce the aggregate payoff, as in models in the first group when contributions below the threshold are not refunded; moreover, individual payoffs depend nonlinearly on total contributions, as in models in the second group. However, there are important differences. In models with threshold and no refund, the marginal returns to total contributions are zero up to the threshold, where the group payoff increases discontinuously. This feature supports multiple (symmetric and asymmetric) pure strategy equilibria, which leads to a serious coordination problem. In our games, instead, marginal per capita returns are always positive and the group payoff increases smoothly with total contributions; furthermore, since marginal per capita returns are lower than the marginal cost of contributing, our games do not challenge general freeriding as a benchmark solution based on common(ly known) opportunism. Behaviorally, the rather continuous setup avoids, or at least weakens, the (implicit) focality of the exogenous threshold, and the fact that some equilibria, e.g., equal threshold sharing when games are symmetric, may suggest a possible anchor. Moreover, while in models with interior Nash equilibria individual payoffs are typically a (quadratic) concave function of total contributions, our games rely on a (quadratic) convex payoff function and a non-interior benchmark solution based on common(ly known) opportunism.<sup>7</sup>

Our Milestone condition shares with other studies the idea of a sequence of simultaneous contribution decisions, but differs in the reference model and the scope of the analysis. Duffy et al. (2007), in an experiment based on the model of Marx and Matthews (2000), use a modified linear public goods game that, depending on the treatments, may include a (discontinuous) completion benefit. Their data tend to suggest that average group contributions are larger when participants' contribution decisions are phased within rounds, as opposed to a single decision in each round. A similar conclusion is suggested by the analysis of Choi et al. (2008), who instead use a threshold public goods game.

Other studies feature contribution choices across stages within a round, but with somewhat different characteristics and focus. Freytag et al. (2014) explore the use of milestones as inter-

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<sup>6</sup>See, e.g., Davis and Holt (1993), Ledyard (1995), and Chaudhuri (2011) for surveys.

<sup>7</sup>Among nonlinear public good models, freeriding is also dominant in Isaac et al. (1985) and Isaac and Walker (1991), which, however, maintain the concavity of individual payoffs from contributions.



mediate incentivized targets in a threshold public goods game with phased contribution choices and probabilistic loss if the threshold is not reached. Erkal et al. (2023) examine rather systematically how (payoff irrelevant) information provision about group members' intermediate contributions across stages affects overall contribution rates. Haita-Falah (2021) compares cases with and without first-phase sunk choices in an experiment with only two contribution phases. Gallier and Sturm (2021) investigate the possibility of a ratchet effect in dynamic incentive schemes applied to voluntary contribution games.

Finally, additional experimental analyses consider dynamic contributions with a rather different timing of choices, by letting group members decide either in continuous time (see, e.g., Dorsey, 1992 and Kurzban et al., 2001) or sequentially (see, e.g., Andreoni et al., 2002 and Normann and Rau, 2015).

### 3 Public goods game with increasing returns from contributing

#### 3.1 Baseline condition

The static public goods game of the Baseline condition involves  $n \geq 2$  symmetric contributors endowed with  $e > 0$  (tokens). The individual contribution of participant  $i = 1, 2, \dots, n$  is  $c_i$ , with  $0 \leq c_i \leq e$ , and total contributions are  $C = \sum_i c_i$ , with  $0 \leq C \leq ne$ . The individual payoff is:

$$u_i(c_i, C) = e - c_i + \underbrace{\beta C + \left(\frac{\gamma}{2}\right) C^2}_{r(C)}, \quad (1)$$

with  $r(C)$  being the return from contributing when aggregate contribution is  $C$ . We assume  $0 < \beta < 1/n$ ,  $\gamma > 0$ , and

$$\beta + \gamma ne < 1 \quad (2)$$

Therefore marginal returns from contributing,  $r'(C) = \beta + \gamma C$ ,<sup>8</sup> are always positive and increase linearly with the total contribution, but are always smaller than the marginal cost of contributing: the individual payoff monotonically decreases with the own contributions for any given contribution level of the other contributors.

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<sup>8</sup>Hereafter, we let  $r'(C)$  denote the derivative  $dr(C)/dc_i$ .

Now, let  $\underline{C}$  be defined via  $nr'(\underline{C}) = 1$  and consider the aggregate payoff:<sup>9</sup>

$$u(C) = \sum_i u_i(c_i, C) = ne - C + nr(C),$$

$u(C)$  decreases with total contributions for  $C < \underline{C}$  because the aggregate marginal return being lower than the marginal cost of contributing ( $nr'(C) < 1$ ). So small total contributions are inefficient in the sense that  $u(C) < u(0)$ . However,  $u(C)$  monotonically increases when  $C > \underline{C}$  due to  $nr'(\underline{C}) > 1$ . So, the initial decrease in aggregate payoff may be recovered via additional contributions with increasing marginal returns. If  $u(ne) > u(0)$ , then fully contributing payoff dominates universal freeriding; specifically,  $nr(ne) > ne$  occurs if

$$n \left( \beta + \frac{\gamma ne}{2} \right) > 1. \quad (3)$$

When conditions (2) and (3) hold, i.e., when<sup>10</sup>

$$2 \left( \frac{1}{n} - \beta \right) < \gamma ne < 1 - \beta, \quad (4)$$

a social dilemma arises.

Furthermore, let  $\overline{C}$  be defined via  $u(\overline{C}) = u(0)$ , i.e., via  $nr(\overline{C}) = \overline{C}$ .<sup>11</sup> For  $C < \overline{C}$ , one is in “the region of suffering” with contributions reducing aggregate payoff, i.e.,  $u(C) < u(0)$ . On the other hand,  $C > \underline{C}$  goes beyond suffering, i.e., the negative effect of low contributions on aggregate payoff is compensated, so that  $u(C) > u(0)$ .

Figure 1(a) illustrates the marginal return  $r'(C)$ , and Figure 1(b) the aggregate payoff  $u(C)$ , for all possible  $C$ -levels, as well as the threshold values  $\underline{C}$  and  $\overline{C}$ . The diagrams capture in a static way the fact that providing more or better public goods can be initially costly rather than efficiency increasing: freeriding ( $C = 0$ ), the benchmark solution based on common opportunism, is a local maximum for  $u(C)$  but is payoff dominated by fully contributing ( $C = ne$ ).

Finally, we exclude that a single participant alone can go beyond suffering within a group by assuming  $\overline{C} > e$ , i.e.,

$$2 \left( \frac{1}{n} - \beta \right) > \gamma e \quad (5)$$

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<sup>9</sup>Since  $\gamma > 0$ , assuming  $1/n > \beta$  ensures that  $\underline{C} = (1/n - \beta)/\gamma$  is positive.

<sup>10</sup>This condition requires  $2 < n(1 + \beta)$ .

<sup>11</sup>By direct computation,  $\overline{C} = 2(1/n - \beta)/\gamma = 2\underline{C} > 0$ .

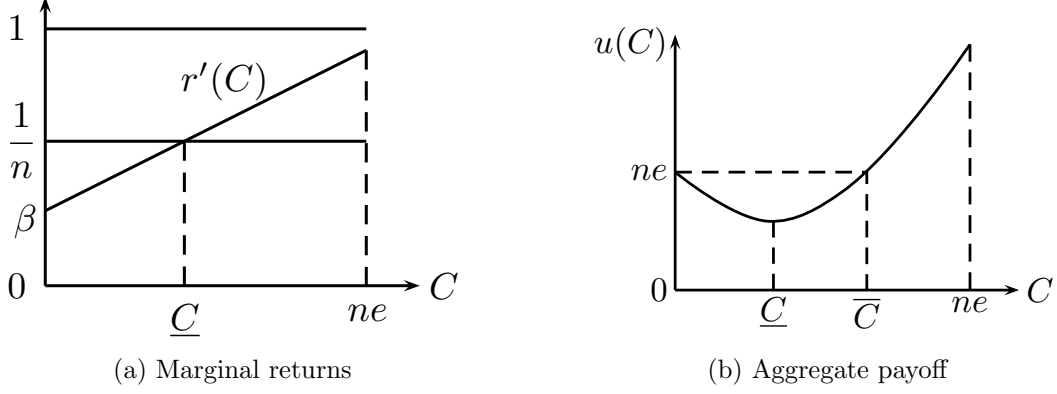


Figure 1: Marginal returns to contributions, aggregate payoff, and the region of suffering

### 3.2 Milestone condition

In the Milestone condition, participants can contribute to the public good provision across finitely many stages  $t = 1, 2, \dots, s$ , with their payoffs depending on their total contributions across stages. Specifically, let  $c_{it}$  and  $C_t = \sum_i c_{it}$  denote the individual and aggregate contributions at stage  $t$ , respectively, and let  $c_i = \sum_{t=1}^s c_{it}$  and  $C = \sum_{t=1}^s C_t$  denote the total individual and aggregate contributions, respectively. As in the Baseline condition,  $(c_i, C)$  determine the individual payoff via (1).

The Mileston condition assumes binary contribution choices  $c_{it} \in \{0, \bar{e}\}$ , with  $\bar{e} = e/s$ , for each stage  $t$ . Thus, participants cannot make up for missed contributions on previous stages and must contribute on all stages when aiming at the maximal total aggregate contribution  $C = ne$ .

If we assume that all participants expect the other group members to be opportunistic, then by backward induction the benchmark solution prescribes  $c_{it} = 0$  for all  $t = 1, \dots, s$  and all  $i = 1, \dots, n$  also in the Milestone condition.

However, since participants receive feedback on  $C_t$  after each stage  $t$ , they can condition their current decisions on past ones, what allows for reciprocity and reputation building in the sense of Kreps et al. (1982). The key idea of reputation equilibrium is to postulate participant types who are intrinsically motivated to cooperate, what allows opportunistic participants to hide their opportunism by mimicking cooperative behavior. The theoretical analysis simply assumes that the intrinsically motivated type exists with (commonly known) probability  $\lambda \in (0, 1)$ . In fact, in the tradition of reputation equilibria, the probability  $\lambda$  with which one expects others to be intrinsically motivated is only postulated, i.e., the experimental instructions do not even mention the possibility of these types.

Our Milestone condition assumes that intrinsically motivated participants will contribute  $\bar{e}$  as long as no one has failed to contribute before, i.e., they will contribute even on the last stage if everyone has contributed in all previous stages. We therefore consider a (mixed strategy) equilibrium in which

- $i$  contributes  $c_{it} = \bar{e}$  for every  $t < s - 1$ , but
- in stage  $s - 1$  contributes  $c_{is-1} = \bar{e}$  only with probability  $p_i \in [\lambda, 1)$  and expects other opportunistic participants  $j \neq i$  to do so only with probability  $p_j \in [\lambda, 1)$  and finally,
- on stage  $s$ , contributes  $c_{is} = 0$  with certainty.

An explicit characterization of the reputation equilibrium for the actual experimental implementation of the Milestone condition is presented in the next section, while additional analyses are presented in Appendix A. Overall, it is clear that the aggregate contributions in a reputation equilibrium are positive in the early rounds, and thus higher than the contributions of the dominant strategy equilibrium of the Baseline condition.

## 4 Experimental Implementation and Protocols

The experimental implementation assumes  $\beta = 10/75$ ,  $\gamma = 1/75$ ,  $n = 3$ , and  $e = 20$ .<sup>12</sup> Furthermore, it allows for total individual contributions  $c_i \in \{0, 5, 10, 15, 20\}$ , with  $i = 1, 2, 3$ . For the aggregate contributions  $C \in \{0, 5, 10, \dots, 50, 55, 60\}$  and for any 5-unit increase, the marginal returns per unit are hold constant at  $r'(C)$ . Thus, the increase  $r(C) - r(\hat{C})$  from  $\hat{C}$  to  $C = \hat{C} + 5$  is  $r'(C)(C - \hat{C}) = 5r'(C)$  and the (continuous) returns function  $r(C)$  is approximated by

$$r_d(C) = 5 \left( \sum r'(\tilde{C}) \right), \quad (6)$$

with the summation across  $\tilde{C}$ -levels running over all 5-unit increments up to  $C$ . This implies that the (continuous) aggregate payoff  $u(C)$  is approximated via  $u_d(C) = ne - C + nr_d(C)$ . Table 1 presents all possible values of the aggregate contribution  $C$ , the approximate marginal return  $r'(C)$ , the approximate return  $r_d(C)$ ,<sup>13</sup> and the approximate aggregate payoff  $u_d(C)$ . Additionally, Figure 2 compares the continuous,  $r(C)$ , with the approximate,  $r_d(C)$ , return from contributing.

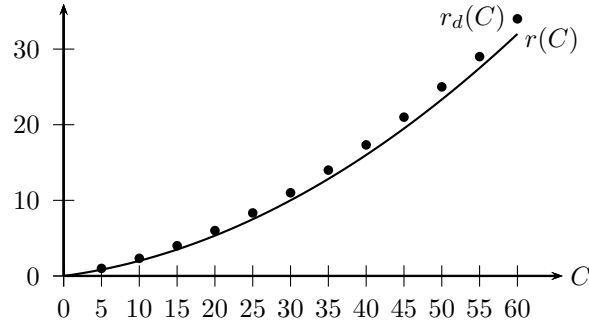
<sup>12</sup>These values are consistent with conditions (4) and (5).

<sup>13</sup>These values are given by (6), so that, for instance,  $r_d(10) = 5r'(5) + 5r'(10) = 5(3/15) + 5(4/15) = 7/3$ .

Table 1: Continuous  $r'(C)$  and approximate  $r_d(C)$  marginal returns, and aggregate payoff  $u_d(C)$

$C$	0	5	10	15	20	25	30	35	40	45	50	55	60
$r'(C)$	0	$\frac{3}{15}$	$\frac{4}{15}$	$\frac{5}{15}$	$\frac{6}{15}$	$\frac{7}{15}$	$\frac{8}{15}$	$\frac{9}{15}$	$\frac{10}{15}$	$\frac{11}{15}$	$\frac{12}{15}$	$\frac{13}{15}$	$\frac{14}{15}$
$r_d(C)$	0	$\frac{3}{3}$	$\frac{7}{3}$	$\frac{12}{3}$	$\frac{18}{3}$	$\frac{25}{3}$	$\frac{33}{3}$	$\frac{42}{3}$	$\frac{52}{3}$	$\frac{63}{3}$	$\frac{75}{3}$	$\frac{88}{3}$	$\frac{102}{3}$
$u_d(C)$	60	58	57	57	58	60	63	67	72	78	85	93	102

Figure 2: The continuous  $r(C)$  and approximated  $r_d(C)$  return function



Due to  $\underline{C} \in \{10, 15\}$ ,  $\bar{C} = 25$ , and  $e = 20$ , no group member can go beyond suffering alone. And if all group members contribute 10 tokens, i.e., half of their endowment, the aggregate payoff (63) is only slightly higher than that in case of general freeriding.

The Baseline condition simply implements the public goods game described in Section 3.1, with the above parameters, as one-off interaction. The Milestone condition, instead, uses a sequential protocol with four contribution stages, so that  $s = 4$ ,  $\bar{e} = 20/4 = 5$  and  $c_{it} \in \{0, 5\}$  for  $t = 1, \dots, 4$ . Therefore, given our parametrizations, the expected payoff of an opportunistic participant  $i$  in a reputation equilibrium is computed as follows (using (15) in Appendix A):

$$\begin{aligned}
 & p_i 5 + p_i \prod_{j \neq i} p_j [\lambda^2 r(55) + 2\lambda(1 - \lambda)r(50) + (1 - \lambda)^2 r(45)] + \\
 & (1 - p_i)10 + (1 - p_i) \left[ \prod_{j \neq i} p_j r(40) + \sum_{j', j' \neq i} p_{j'}(1 - p_j)r(35) + \prod_{j \neq i} (1 - p_j)r(30) \right]
 \end{aligned}$$

For symmetric equilibria with  $p_i = p$  and  $i = 1, 2, 3$ , the expected payoff becomes

$$p5 + p^3 [\lambda^2 r(55) + 2\lambda(1 - \lambda)r(50) + (1 - \lambda)^2 r(45)] + \\ (1 - p)10 + (1 - p) [p^2 r(40) + 2p(1 - p)r(35) + (1 - p)^2 r(30)].$$

Substituting the  $r(\cdot)$ -values from Table 1, and given  $\lambda \in (0, 1)$ , participant  $i$  to be indifferent between the choices  $c_{i3} = 0$ , which reveal opportunism in stage 3, and  $c_{i3} = 5$ , which delays such revelation, endgame equilibrium mixing requires  $\hat{p} \in [\lambda, 1)$  with

$$5 + \hat{p}^2 [\lambda^2(29.3) + 2\lambda(1 - \lambda)(25) + (1 - \lambda)^2(21)] = 10 + [\hat{p}^2(17.3) + 2\hat{p}(1 - \hat{p})(14) + (1 - \hat{p})^2(11)]$$

Via numerical and graphical analyses,<sup>14</sup> one verifies that there is a non-empty interval for  $\lambda$  such that  $\hat{p} \in [\lambda, 1)$  satisfies the required indifference condition.

#### 4.1 Experiment 1: Baseline protocol

In Experiment 1 we implement the Baseline condition. Specifically we experimentally implement the public goods game described above as one-off interaction and allow for extensive learning via repeated play based on random strangers rematching within matching groups of six participants.<sup>15</sup> Participants receive feedback on total contributions after each round in Baseline and also after each stage in Milestone. Participants play 30 rounds, and they are aware that they do not interact with the same two other participants in two consecutive rounds. At the end of each round, they receive feedback information about the own and the others' total contributions, as well as own payoff.<sup>16</sup> One round is randomly selected for payment.

The sessions, which lasted at most 90 minutes, were run in April and May 2021. Due to the Covid19 pandemic, we ran the experiment using the lab-like protocol of Buso et al. (2021) with students from LUISS Guido Carli University (Rome, IT) recruited via Orsee (Greiner, 2015). After reading the instructions, participants answered control questions to test their understanding of the payoff rules. Participants were constantly monitored by experimenters and paid privately via PayPal immediately at the end of each session. The average payment

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<sup>14</sup>The numerical analysis is performed via queries to ChatGPT and the graphical analysis via Desmos; see Appendix A for details.

<sup>15</sup>In both conditions, the size of the matching group is chosen for the sake of independence of the observations, taking into account the cost-effectiveness of the design and the usual experimental practices.

<sup>16</sup>Appendix C reports the instructions for the Baseline condition.

was equal to 15.04€, including the show-up fee of 5€. The experiment was programmed via oTree (Chen et al., 2016). Altogether, there were 17 rematching groups.

## 4.2 Experiment 2: Milestone protocol

In Experiment 2 we implement the Milestone condition. Specifically, the Milestone protocol is based on four successive stages, which constitute one round: on each stage one can increase the own contribution by 5 units or abstain from doing so. At the end of each stage, participants receive feedback information on own and total contributions up to that stage. After the fourth stage, the round ends and participants receive feedback information about the cumulated total contributions and their own payoff.<sup>17</sup> Participants play for 12 rounds, what allows for extensive learning given the four phased choices in each round.<sup>18</sup> They interact with the same two other group members during the four stages of a round. Across rounds, they are randomly rematched within matching groups of six participants and are aware that they do not interact with the same two other participants in two consecutive rounds. One round is randomly selected for payment.

The sessions, which lasted at most 90 minutes, were organized in presence during June 2024 at the CESARE Lab of Luiss Guido Carli (Rome, IT) with students from the same university who had not participated in the Baseline condition. Participants were recruited via Orsee (Greiner, 2015) and paid at the end of the each session. After reading the instructions, participants answered control questions to test their understanding of the payoff rules. The average payment was equal to 23.05€, including the show-up fee of 5€. The experiment was programmed via oTree (Chen et al., 2016). Altogether, also in this condition there were 17 rematching groups.

## 5 Empirical strategy and results

The focus of our analyses is twofold. At the individual level, we examine the contribution choices and their determinants; at the group level, we analyze how individual behavior determines whether the group goes beyond suffering. Separately for each condition, we present descriptive statistics and regression analyses. To study individual contributions, we use a random-effect

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<sup>17</sup>Appendix D reports the instructions for the Milestone condition.

<sup>18</sup>Relative to the Baseline protocol, the number of rounds was adjusted to maintain a homogeneous time frame between the two conditions.

tobit model to account for the longitudinal structure of our data and the censored distribution of contributions due to the lower ( $c_{i,t} = 0$ ) and upper ( $c_{i,t} = 20$ ) bounds. Furthermore, we use matching-group dummies to control for the within-group dependence, generated by the rematching protocol. When analysing group-level outcomes, our protocols rule out any panel-data approach, due to the non-fixed group composition and the two outcomes per round for every matching group. Therefore, we examine the groups' probability of going beyond suffering using a probit model with standard errors clustered at the matching group level.

When specifying our models, we rely on well-established results in the literature analyzing the voluntary contribution mechanisms. We expect to observe path dependence in individual contribution choices, shaped by intrinsic preferences for cooperation (or freeriding), and we test for it by including the last contribution choice in the individual contribution analysis. Similarly to Gunnthorsdottir et al. (2007), we use one's own first-round behavior, which is unaffected by feedback, as an indicator of intrinsic preferences for cooperation. Group's first-round behavior, which accounts for its composition of cooperators and freeriders, is used to test whether interacting with more cooperative members induces higher contributions in later rounds (Gächter and Thöni, 2005) and its effects on the (matching) group's ability to go beyond suffering. In the Baseline condition, we test whether first-round experience has an imprinting effect in affecting later contributions. We do not expect such an effect in the Milestone condition, whose participants can rely on stage-wise feedback to infer the group's cooperativeness.

Although groups are rematched in every round, the absence of other coordination mechanisms might induce participants in the Baseline condition to use others' past contributions as an anchor, whereas in Milestone participants could directly respond to choices in previous stages. For conditional cooperation (Fischbacher et al., 2001), we expect to observe declining contributions, due to the usual discouraging of conditional cooperators who interact with freeriders.

## 5.1 Results: Baseline

Figure 3 illustrates the dynamics of average individual contributions  $c_i$ , with 95% confidence intervals, (panel *a*) and of group-level outcomes, i.e., freeriding rates and the percentage of groups with aggregate contributions  $C$  at least equal to 30 (panel *b*). The overall average contribution is low, 4.489 (standard deviation of 6.049), due to the high frequency of freeriding



(54.28%) and the stable decline across time, confirmed by Kendall’s rank correlation.<sup>19</sup> In fact, only in few instances (17.65%) the groups went beyond suffering. In addition, panel *b* clearly shows that such successful instances mostly occur in initial rounds, while the frequency of freeriding increases across rounds.<sup>20</sup>

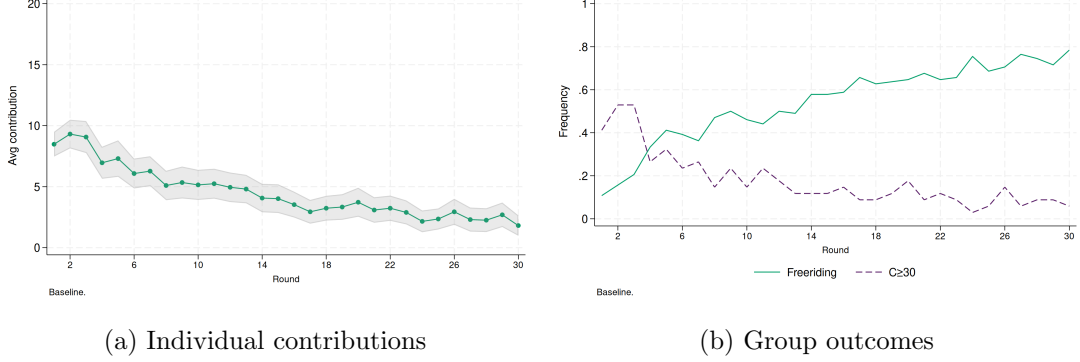


Figure 3: Dynamics of individual average contributions (a) and group outcomes (b) in Baseline

To investigate the determinants of individual contributions, Table 2 reports the results of random-effect tobit models with  $c_{i,t}$ , i.e., the individual contribution  $c_i$  at round  $t$ , as dependent variable. In what follows,  $g$  denotes the three-player group which includes player  $i$  in round  $t$ .<sup>21</sup> All specifications include, among the regressors, the previous-round own contribution ( $c_{i,t-1}$ ), the average contribution of the other two group members ( $\bar{c}_{-i,t-1}$ ), a round variable and matching group dummies.<sup>22</sup> Model 1 and Model 2 only differ by the demographics (age, whether studying Economics or not, gender, and experience in laboratory experiments), which are included also in the remaining models. In Model 3,  $\bar{c}_{-i,t-1}$  is replaced by the dummy variable ( $C_{g,t-1} \geq 30$ ) indicating whether group  $g$  went beyond suffering in the previous period  $t-1$ . To account for initial choices, Model 4 includes the first-round average group contribution ( $\bar{c}_{g,t=1}$ ), while Model 5 includes separately initial own ( $c_{i,t=1}$ ) and others’ ( $\bar{c}_{-i,t=1}$ ) average contribution.

Results confirm significant inertia: larger own contributions in the previous round inspire greater ones in the current round. Despite the randomly changing group members, the average contribution of the two former partners affects one’s own current contribution: participants

<sup>19</sup> $\tau = -0.867$  with  $p$ -value = 0.000 when the unit of observation is the average contribution at round  $t$  of all members in the Baseline condition (i.e., 30 independent observations in total) and  $\tau = -0.371$  with  $p$ -value = 0.000 when the unit of observation is the average contribution at the matching group level.

<sup>20</sup>In Appendix A, Figure 5 shows the dynamics of average contributions separately for the 17 matching groups.

<sup>21</sup>In every round, there are two such  $g$ -groups in each matching group.

<sup>22</sup>In the Appendix, Table 6 reports the coefficients of the same random-effects tobit models with standard errors clustered at the matching group level (and without matching-group dummies), while Table 7 reports the results of the equivalent three-nested level models, with observations nested within individuals nested within matching groups; the estimates lead to comparable conclusions.

Table 2: Determinants of individual contribution at round  $t$  in Baseline

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.261*** (0.0393)	0.262*** (0.0393)	0.224*** (0.0426)	0.261*** (0.0393)	0.261*** (0.0393)
$\bar{c}_{-i,t-1}$	0.268*** (0.0516)	0.267*** (0.0516)		0.267*** (0.0516)	0.267*** (0.0516)
$C_{g,t-1} \geq 30$			1.656*** (0.586)		
$\bar{c}_{g,t=1}$				0.799** (0.391)	
$c_{i,t=1}$					0.284* (0.164)
$\bar{c}_{-i,t=1}$					0.517* (0.276)
Round	-0.426*** (0.0288)	-0.426*** (0.0288)	-0.476*** (0.0269)	-0.427*** (0.0288)	-0.427*** (0.0288)
Constant	-1.962 (2.806)	-5.526 (6.771)	-4.088 (6.690)	-9.874 (6.968)	-9.859 (6.970)
Observations	2,958	2,958	2,958	2,958	2,958
Number of subjects	102	102	102	102	102
Demographics	✗	✓	✓	✓	✓
Matching group dummies	✓	✓	✓	✓	✓
Left-censored obs.	1650	1650	1650	1650	1650
Right-censored obs.	183	183	183	183	183
Wald $\chi^2$	648	672.2	661	677.8	677.8
Prob $> \chi^2$	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from random-effect tobit regression with individual contribution at round  $t$  as truncated dependent variable. All specifications include matching group dummies. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments). A table with coefficients for all controls and dummies is available in the online repository.

seem to anchor their choices on past outcomes.<sup>23</sup> Furthermore, belonging to a group which went beyond suffering in the previous round also encourages current contributions (see Model 3). It is then straightforward that such a strong evidence of conditional cooperation, together with the high frequency of freeriding choices observed in the descriptive statistics, leads to declining contributions. This result is also reinforced by the negative coefficients of the round variable, which captures the overall declining trend due to the cumulative effects of all past interactions.

Our analysis strongly suggests that the initial, feedback-free, experience shapes subsequent interactions. In particular, Model 4 highlights how the outcome of the initial ( $t = 1$ ) round affects later contributions: higher average group contribution in the first round significantly boosts later individual cooperation. Distinguishing between own and others' initial contribution (weakly) confirms this result (Model 5).<sup>24</sup> We interpret this result as evidence of the relevance of the initial (matching) group composition, since first-round choices can be seen as indicators of intrinsic willingness to (not) cooperate.

To further investigate this aspect, we analyze the probability that a group goes beyond suffering, with a specific focus on its composition. To this end, we define:

$$\delta_{g,t} = \begin{cases} 1 & \text{if } C_{g,t} \geq 30 \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

where  $g$  denotes a three-player group randomly formed in period  $t$ .<sup>25</sup>

Table 3 reports the marginal effects of three probit models with  $\delta_{g,t}$  as dependent variable, and standard errors clustered at the matching group level. All specifications include demographic and round variables. The controls are averaged at the same level as the dependent variable, taking into account the randomly changing groups. In particular, averages are taken across participants belonging to group  $g$  in the current round and are based on the average group values experienced by these participants in earlier rounds, i.e., on average choices of their

<sup>23</sup>Figure 6 (upper panel) in Appendix A plots the average individual contribution at the matching group level for each round ( $y$  axis) against the average contributions of the other group members at the matching group level in the last period ( $x$  axis). Despite a clear positive correlation between average individual contributions in period  $t$  and average contribution of the two partners in  $t - 1$ , the Figure also reveals a considerable heterogeneity of reactions to the same level of partners' past contributions. Distinguishing the first (last) 6 rounds reveals less heterogeneity of later reactions, which mostly converge to freeriding (see Figure 6, lower panel).

<sup>24</sup>We find that experienced male participants contribute significantly less than unexperienced male participants, while the effect does not hold for female participants. We do not find a significant gender difference nor other demographics are found to influence individual contributions.

<sup>25</sup>Note that in every round we have two such  $g$ -groups in every matching group.

Table 3: Determinants of the probability of going beyond suffering in Baseline

Dependent variable: $\delta_{g,t}$			
	(1)	(2)	(3)
Avg. $\bar{c}_{g,t-1}$	0.030*** (0.003)	0.031*** (0.003)	0.033*** (0.004)
Avg. $\bar{c}_{g,t=1}$	0.016*** (0.005)		
Avg. $\delta_{g,t=1}$		0.091*** (0.025)	
Avg. freeriding $_{g,t=1}$			-0.272*** (0.098)
Round	-0.003 (0.002)	-0.003 (0.002)	-0.002 (0.002)
Demographics	✓	✓	✓
Observations	986	986	986
% correct. class	88.84	88.34	88.74

The dependent variable is a dummy variable equal to one if the three-player group went beyond suffering in round  $t$  and 0 otherwise; given the random strangers rematching protocol, the lagged and period-one covariates are averaged across the three members that form a group in the current round. Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Marginal effects from probit regressions with standard errors clustered at the matching group level. All specifications include the composition of the three-player group in terms of gender, age, students in Economics and experience in lab experiments. The last row reports the percentage of correctly classified observations. A table with coefficients for all controls is available in the online repository.

(different) group in the previous or the first round. Therefore, they measure the average cooperation attitude experienced by currently interacting participants in their previous or first round interactions. All models include the average contribution in the previous round (Avg.  $\bar{c}_{g,t-1}$ ) and differ in the specification of first-round choices: Model 1 includes the average group contribution in the first round (Avg.  $\bar{c}_{g,t=1}$ ); Model 2 accounts for whether, in the first round, the group went or not beyond suffering (Avg.  $\delta_{g,t=1}$ ); Model 3 includes the frequency of group freeriding,  $c_i = 0$ , choices in the first round (Avg. freeriding $_{g,t=1}$ ).

Consistently with the results on individual choices, these models confirm significant group inertia: a group is more likely to go beyond suffering in the current round when its members have experienced, on average, higher contributions in their last interaction. Furthermore, whether group members are more or less cooperative influences the probability of going beyond suffering, since this is positively associated with the average group contribution in the first round (Model 1) and also with the frequency of going beyond suffering (Model 2). Interestingly, freeriding

plays a predominant role (Model 3): the presence of freeriders in the initial interaction reduces the groups' propensity to cooperate in later rounds.<sup>26</sup>

## 5.2 Results: Milestone

The individual choice dynamics in the Milestone condition are shown in panel *a* of Figure 4, while the dynamics of freeriding and going beyond suffering are shown in panel *b* of Figure 4.<sup>27</sup> The average individual contribution is 10.633 (standard deviation 7.461), while full contribution ( $c_i = 20$ ) occurs with a frequency of 25.90%. Regarding the evolution of contributions across rounds, Kendall's rank correlation confirms the presence of a declining trend in contributions also in Milestone,<sup>28</sup> although they remain substantial across rounds, with an average contribution in the last ( $t = 12$ ) round of 9.265. Interestingly, the maximal aggregate contribution ( $C = 60$ ) occurs with a frequency of 9.56%; this descriptive observation hints at the fact that the Milestone condition facilitates going beyond suffering. Panel *b* of Figure 4, however, shows that freeriding is present also in this condition: overall, in 22.06% of cases participants did not contribute on all four stages of a round. Furthermore, its increasing trend contributes to the decreasing frequency of going beyond suffering.

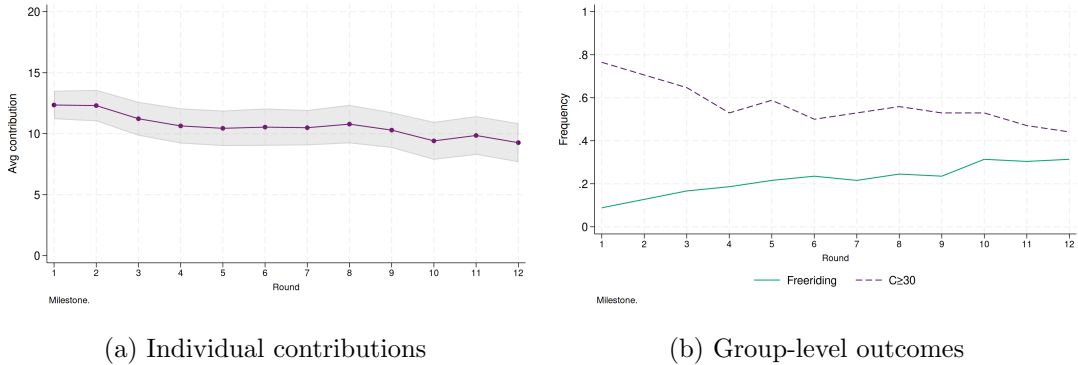


Figure 4: Dynamics of individual average contributions (a) and of group-level outcomes (b) in Milestone

To analyze the determinants of individual contributions, we follow the same strategy as in Baseline, with the exception of the variable controlling for conditional cooperation. Since

<sup>26</sup>The composition in terms of demographics of the player group does not affect this probability.

<sup>27</sup>As for Baseline, Figure 7 in Appendix A shows the dynamics of average contributions separately for the 17 matching groups.

<sup>28</sup>As for Baseline, the test is performed both on the average contribution at round  $t$  of all members in the Milestone condition as independent units of observation (i.e., 12 observations in total), which results on  $\tau = -0.788$  with  $p$ -value = 0.001, and on the average contribution at the matching group level, with  $\tau = -0.110$  and  $p$ -value = 0.022.

the Milestone protocol provides a coordination device via stage-wise information feedback, we replace the average contribution of other group members in period  $t - 1$  ( $\bar{c}_{-i,t}$ ) with the average choices of one's current partners in the first stage of round  $t$  ( $\bar{c}_{-i,s=1,t}$ ).

Results are reported in Table 4<sup>29</sup> and confirm the predicted regularities: participants exhibit not only significant path dependence, but also condition their contributions on others' first-stage choices. This makes it clear that in Milestone participants substitute past interaction outcomes, as observed in Baseline, by intermediate feedback information.<sup>30</sup> The stage-wise information feedback also renders insignificant the effect of having successfully gone beyond suffering with the previous period partners (Model 3). The composition in terms of intrinsic cooperativeness of the group met in the first round seems to be a determinant of own current contributions (Model 4); however, distinguishing others' type from the own one (Model 5) reveals that only the latter has a significant effect. So, Milestone prevent any imprinting effect of early interactions on current individual contributions. The declining trend of contributions, already shown via descriptive statistics, is confirmed by the negative and statistically significant coefficient of the round variable.

Table 5 reports the results of regression analyses when the dependent variable is the probability of group  $g$  going beyond suffering in round  $t$ . Following the econometric strategy illustrated at the beginning of the Section to cope with two randomly formed groups within each matching group, we resort to a probit model with standard errors clustered at the matching group level and use the same covariates as in Baseline.

Results show, once again, that going beyond suffering is not only path dependent, but also strongly affected by the group composition, proxied by the average contributions which the group has experienced in the first round. In particular, a group is more likely to go beyond suffering when its members have confronted more cooperators ( $\bar{c}_{g,t=1}$ ) and less freeriders (Avg. freeriding $_{g,t=1}$ ) in the first round.

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<sup>29</sup>As before, we report in the Appendix the results of the same model with standard errors clustered at the matching-group level (Table 8) and those of the analogue three-level nested models (Table 9), which show qualitatively similar results.

<sup>30</sup>Results of the same specifications used for Baseline are reported in Table 10 in the Appendix and show that, in Milestone, individual's contribution in round  $t$  are not correlated with past partners' contributions.

Table 4: Determinants of individual contribution at round  $t$  in Milestone

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.283*** (0.057)	0.285*** (0.057)	0.348*** (0.074)	0.282*** (0.057)	0.274*** (0.057)
$\bar{c}_{-i,s=1,t}$	0.881*** (0.095)	0.880*** (0.095)		0.879*** (0.095)	0.884*** (0.094)
$C_{g,t-1} \geq 30$			-0.310 (0.880)		
$\bar{c}_{g,t=1}$				0.797** (0.333)	
$c_{i,t=1}$					0.746*** (0.150)
$\bar{c}_{-i,t=1}$					0.071 (0.226)
Round	-0.234*** (0.087)	-0.235*** (0.087)	-0.319*** (0.092)	-0.235*** (0.087)	-0.238*** (0.087)
Constant	6.285* (3.231)	-1.362 (7.913)	5.728 (7.370)	-11.317 (8.752)	-8.564 (8.084)
Demographics	✗	✓	✓	✓	✓
Matching group dummies	✓	✓	✓	✓	✓
Observations	1,122	1,122	1,122	1,122	1,122
Number of subjects	102	102	102	102	102
Left-censored obs.	261	261	261	261	261
Right-censored obs.	294	294	294	294	294
Wald $\chi^2$	217.7	224.1	164.4	234.2	266.6
Prob $> \chi^2$	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from random-effect tobit regression with individual contribution at round  $t$  as truncated dependent variable. All specifications include matching group dummies. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments).  $\bar{c}_{-i,s=1,t}$  indicates the average contribution of the other two group members in the first stage of the current round. A table with coefficients for all controls and dummies is available in the online repository.

Table 5: Determinants of the probability of going beyond suffering in Milestone

	Dependent variable: $\delta_{g,t}$		
	(1)	(2)	(3)
Avg. $\bar{c}_{g,t-1}$	0.037*** (0.006)	0.047*** (0.005)	0.043*** (0.005)
Avg. $\bar{c}_{g,t=1}$	0.031*** (0.008)		
Avg. $\delta_{g,t=1}$		0.148* (0.086)	
Avg. freeriding $_{g,t=1}$			-0.538*** (0.186)
Round	-0.008 (0.005)	-0.005 (0.006)	-0.006 (0.005)
Demographics	✓	✓	✓
Observations	374	374	374
% correct. class	79.95	77.54	78.88

The dependent variable is a dummy variable equal to one if the three-player group went beyond suffering in round  $t$  and 0 otherwise; given the random strangers rematching protocol, the lagged and period-one covariates are averaged across the three members that form a group in the current round. Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Marginal effects from probit regressions with standard errors clustered at the matching group level. All specifications include controls for the composition of the three-player group in terms of gender, age, students in Economics and experience in lab experiments. The last row reports the percentage of correctly classified observations. A table with coefficients for all controls is available in the online repository.



## 6 Conclusions

Based on our analysis, the behavior of the participants is quite clear. In the Baseline condition, cooperation is rare: few groups manage to go beyond suffering, and average contributions tend to converge to general free riding, especially as participants gain experience. Cooperative behavior is generally limited to the first round, where few groups reach average contributions close to half of their individual endowments. In the Milestones condition, on the other hand, total contributions are fairly sustained, even in later rounds, and overcoming of suffering is rather successful, although overall full contributions remain rare. In our view, this evidence is very encouraging and suggests that the Milestone condition can be seen as an effective way to enhance voluntary cooperation, in particular by making individual choice elicitation more informative about others' willingness to cooperate.

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## Appendix A - Additional equilibrium analyses

Given the final stage equilibrium choices described in Section 3.2, we compute the expected payoff at stage  $s - 1$  of a participant  $i$  who is not conditionally cooperative by first considering the case where  $i$  chooses  $c_{is-1} = \bar{e}$  and then the case where  $i$  chooses  $c_{is-1} = 0$ .

If  $c_{is-1} = \bar{e}$ , the remaining endowment, which accrues to  $i$  with probability  $p_i$ , is

$$e - \sum_{t=1}^{s-1} c_{it} = e - (s-1)\bar{e} = \bar{e}, \quad (8)$$

since  $\bar{e} = e/s$ . To compute the payoff from contributing, note that with probability  $\prod_i p_i$  all group members contribute in stage  $s - 1$ , what let conditional cooperators also contribute in the last stage, while the other types freeride on stage  $s$ . The probability that  $k$  group members, where  $0 \leq k \leq n - 1$ , are conditional cooperative is

$$\binom{n-1}{k} \lambda^k (1-\lambda)^{n-1-k},$$

in this case the total aggregate contribution  $C$  is

$$\sum_{t=1}^{s-1} C_t + C_s = (s-1)n\bar{e} + k\bar{e} = ne - (n-k)\bar{e}, \quad (9)$$

since  $C_t = n\bar{e}$  for  $t = 1, 2, \dots, s-1$  and  $\bar{e} = e/s$ , and the payoff from contributing is  $r(ne - (n-k)\bar{e})$ . From (1) it follows that the payoff of choosing  $c_{is-1} = \bar{e}$  with probability  $p_i$ , while expecting the others to do the same with probability  $p_j$  for  $j \neq i$  is

$$p_i \left\{ \bar{e} + \prod_{j \neq i} p_j \left[ \sum_{k=0}^{n-1} \binom{n-1}{k} \lambda^k (1-\lambda)^{n-1-k} r(ne - (n-k)\bar{e}) \right] \right\}. \quad (10)$$

If  $c_{is-1} = 0$ , the remaining endowment, which accrues to  $i$  with probability  $1 - p_i$ , is

$$e - \sum_{t=1}^{s-2} c_{it} = e - (s-2)\bar{e} = 2\bar{e}. \quad (11)$$

When  $i$  does not contribute in the penultimate stage, the conditional cooperators and all other group member do not contribute on the final stage  $s$ . Therefore the total aggregate contribution  $C$  in this case depends on how many group members other than  $i$  contribute on stage  $s - 1$ . We assume that, on this stage, each member  $j \neq i$  contributes with probability  $p_j$ ; therefore,

to compute the likelihood that  $k$  group members, where  $0 \leq k \leq n-1$ , contribute, we use the Poisson Binomial distribution (see, e.g., Tang and Tang, 2023) as follows: let  $\mathcal{A}_k$  denote the collection of all subsets of size  $k$  of the set  $\{1, 2, \dots, n-1\}$  and let  $A$  denote a generic element of  $\mathcal{A}_k$ . Then the probability that  $\mathcal{P}_k$  that  $k$  group members choose  $c_{js-1} = \bar{e}$  is

$$\mathcal{P}_k = \sum_{A \in \mathcal{A}_k} \left( \prod_{j \in A} p_j \prod_{j' \notin A} (1 - p_{j'}) \right); \quad (12)$$

in this case, the total aggregate contribution  $C$  is

$$\sum_{t=1}^{s-2} C_t + C_{s-1} + C_s = (s-2)n\bar{e} + k\bar{e} = ne - (2n-k)\bar{e}, \quad (13)$$

since  $C_t = n\bar{e}$  for  $t = 1, 2, \dots, s-2$ ,  $C_s = 0$  and  $\bar{e} = e/s$ , and the payoff from contributing is  $r(ne - (2n-k)\bar{e})$ . Therefore, from (1) it follows that the payoff of choosing  $c_{is-1} = 0$  with probability  $1 - p_i$ , while expecting the others to choose  $c_{js-1} = \bar{e}$  with probability  $p_j$  for  $j \neq i$  is

$$(1 - p_i) \left\{ 2\bar{e} + \sum_{k=0}^{n-1} \mathcal{P}_k r(ne - (2n-k)\bar{e}) \right\}. \quad (14)$$

To summarize, the expected payoff of a participant  $i$ , who is not conditionally cooperative and chooses  $c_{is-1} = \bar{e}$  with probability  $p_i$ , is

$$p_i \left\{ \bar{e} + \prod_{j \neq i} p_j \left[ \sum_{k=0}^{n-1} \binom{n-1}{k} \lambda^k (1-\lambda)^{n-1-k} r(ne - (n-k)\bar{e}) \right] \right\} + (1-p_i) \left\{ 2\bar{e} + \sum_{k=0}^{n-1} \mathcal{P}_k r(ne - (2n-k)\bar{e}) \right\}. \quad (15)$$

For the numerical analysis of the reputation equilibrium of the Milestone condition (see Section 4), we have used the following prompt to ChatGPT: “For which values of  $\lambda$ , restricted to  $\lambda \in (0, 1)$ , the solution  $x^*$  of the following equation satisfies  $x^* \geq \lambda$  and  $x^* \leq 1$ :  $5 + 29.3x^2\lambda^2 + 50x^2\lambda(1-\lambda) + 21x^2(1-\lambda)^2 = 10 + 17.3x^2 + 28x(1-x) + 11(1-x)^2$ ? Check carefully the upper and the lower bound of the interval.”, where  $x^*$  stands for  $\hat{p}$ .

For the graphical analysis, we have used the graph available at the link <https://www.desmos.com/calculator/2dr4jcs4z0>

## Appendix B - Additional data analyses



Figure 5: Individual and average (matching) group contribution in Baseline

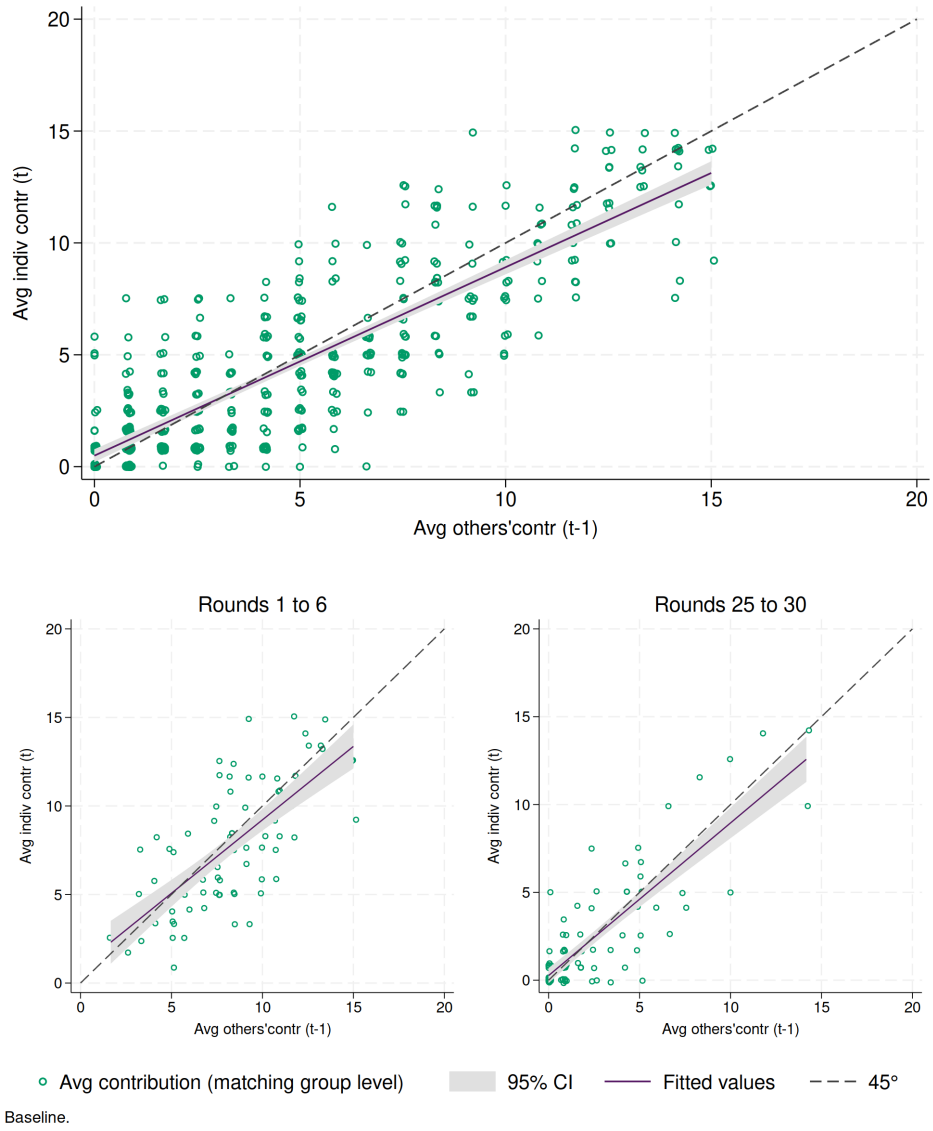


Figure 6: Scatterplot of individual contributions ( $y$  axis) and of other group members' average contribution in the past period ( $x$  axis) with linear interpolation. All rounds (upper panel) and separately for early, first six, rounds and late, last six, rounds (lower panel) in Baseline



Table 6: Determinants of individual contribution at round  $t$  in Baseline; standard errors clustered at the matching-group level

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.271*** (0.059)	0.273*** (0.059)	0.221*** (0.058)	0.268*** (0.059)	0.268*** (0.060)
$\bar{c}_{-i,t-1}$	0.330*** (0.059)	0.333*** (0.059)		0.322*** (0.059)	0.322*** (0.060)
$C_{g,t-1} \geq 30$			2.113*** (0.690)		
$\bar{c}_{g,t=1}$				0.959** (0.452)	
$c_{i,t=1}$					0.340 (0.237)
$\bar{c}_{-i,t=1}$					0.620** (0.285)
Round	-0.408*** (0.056)	-0.407*** (0.056)	-0.471*** (0.066)	-0.411*** (0.056)	-0.411*** (0.056)
Constant	2.148* (1.278)	2.049 (5.909)	5.326 (5.895)	-3.666 (6.851)	-3.653 (6.849)
Observations	2,958	2,958	2,958	2,958	2,958
Number of subjects	102	102	102	102	102
Demographics	✗	✓	✓	✓	✓
Matching group dummies	✓	✓	✓	✓	✓
Left-censored obs.	1650	1650	1650	1650	1650
Right-censored obs.	183	183	183	183	183
Wald $\chi^2$	114.8	175.6	176.3	921.2	1508
Prob $> \chi^2$	0.000	0.000	0.000	0.000	0.000

Standard errors clustered at the matching-group level in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from random-effect tobit regression with individual contribution at round  $t$  as truncated dependent variable. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments). A table with coefficients for all controls is available in the online repository.

Table 7: Determinants of individual contribution at round  $t$  in Baseline, three-level nested models

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.178*** (0.0176)	0.178*** (0.0176)	0.134*** (0.0190)	0.177*** (0.0176)	0.177*** (0.0176)
$\bar{c}_{-i,t-1}$	0.143*** (0.0224)	0.142*** (0.0223)		0.142*** (0.0223)	0.142*** (0.0223)
$C_{g,t-1} \geq 30$			1.787*** (0.279)		
$\bar{c}_{g,t=1}$				0.297*** (0.110)	
$c_{i,t=1}$					0.0940* (0.0492)
$\bar{c}_{-i,t=1}$					0.203** (0.0803)
Round	-0.145*** (0.0112)	-0.145*** (0.0112)	-0.165*** (0.0102)	-0.145*** (0.0112)	-0.145*** (0.0112)
Demographics	✗	✓	✓	✓	✓
Observations	2,958	2,958	2,958	2,958	2,958
Number of subjects	102	102	102	102	102
Number of (matching) groups	17	17	17	17	17

Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from three-level nested model, with subjects nested into matching group, and with individual contribution at round  $t$  as dependent variable. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments).

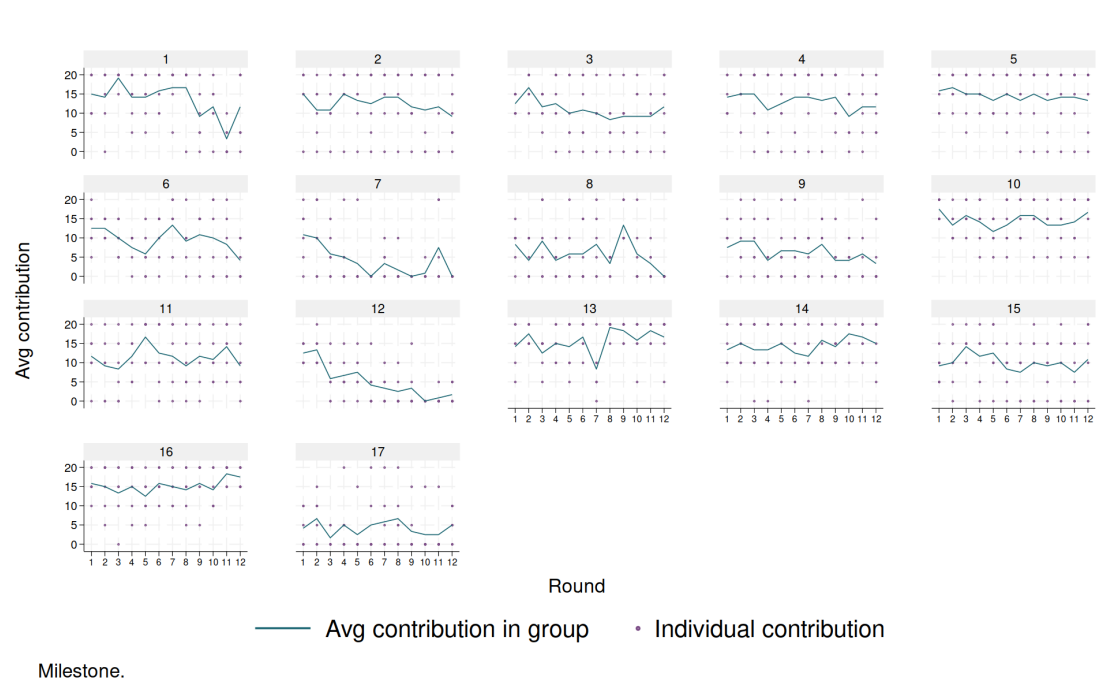


Figure 7: Individual and average (matching) group contribution in Milestone

Table 8: Determinants of individual contribution at round  $t$  in Milestone; standard errors clustered at the matching-group level

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.310*** (0.076)	0.310*** (0.076)	0.310*** (0.086)	0.291*** (0.076)	0.286*** (0.076)
$\bar{c}_{-i,s=1,t}$	0.988*** (0.141)	0.986*** (0.139)		0.938*** (0.134)	0.951*** (0.139)
$C_{g,t-1} \geq 30$			0.699 (0.877)		
$\bar{c}_{g,t=1}$				0.950*** (0.120)	
$c_{i,t=1}$					0.793*** (0.171)
$\bar{c}_{-i,t=1}$					0.166 (0.135)
Round	-0.215* (0.110)	-0.215* (0.110)	-0.304** (0.140)	-0.223** (0.113)	-0.224** (0.113)
Constant	2.443* (1.451)	-1.857 (5.831)	6.017 (6.676)	-11.417* (5.920)	-8.897* (5.196)
Demographics	✗	✓	✓	✓	✓
Observations	1,122	1,122	1,122	1,122	1,122
Number of subjects	102	102	102	102	102
Number of (matching) groups	17	17	17	17	17
Left-censored obs.	261	261	261	261	261
Right-censored obs.	294	294	294	294	294
Wald $\chi^2$	85.71	200.4	25.18	259.6	267.4
Prob > $\chi^2$	0.000	0.000	0.001	0.000	0.000

Standard errors clustered at the matching-group level in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from random-effect tobit regression with individual contribution at round  $t$  as truncated dependent variable. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments).  $\bar{c}_{-i,s=1,t}$  indicates the average contribution of the other two group members in the first stage of the current round.

Table 9: Determinants of individual contribution at round  $t$  in Milestone, three-level nested models

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.178*** (0.028)	0.178*** (0.028)	0.198*** (0.035)	0.175*** (0.028)	0.172*** (0.028)
$\bar{c}_{-i,s=1,t}$	0.510*** (0.049)	0.510*** (0.049)		0.510*** (0.048)	0.515*** (0.048)
$C_{g,t-1} \geq 30$			0.023 (0.473)		
$\bar{c}_{g,t=1}$				0.503*** (0.100)	
$c_{i,t=1}$					0.369*** (0.066)
$\bar{c}_{-i,t=1}$					0.138* (0.083)
Round	-0.123*** (0.046)	-0.123*** (0.046)	-0.174*** (0.048)	-0.124*** (0.046)	-0.124*** (0.046)
Demographics	✗	✓	✓	✓	✓
Observations	1,122	1,122	1,122	1,122	1,122
Number of subjects	102	102	102	102	102
Number of (matching) groups	17	17	17	17	17

Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from three-level nested model, with subjects nested into matching group, and with individual contribution at round  $t$  as dependent variable. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments).  $\bar{c}_{-i,s=1,t}$  indicates the average contribution of the other two group members in the first stage of the current round.

Table 10: Determinants of individual contribution at round  $t$  in Milestone with others' contribution in the last round as independent variable

	Dependent variable: $c_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$c_{i,t-1}$	0.328*** (0.068)	0.330*** (0.068)	0.348*** (0.074)	0.328*** (0.068)	0.312*** (0.067)
$\bar{c}_{-i,t-1}$	0.008 (0.066)	0.008 (0.066)		0.005 (0.066)	0.020 (0.066)
$C_{g,t-1} \geq 30$			-0.310 (0.880)		
$\bar{c}_{g,t=1}$				0.748** (0.313)	
$c_{i,t=1}$					0.693*** (0.144)
$\bar{c}_{-i,t=1}$					0.078 (0.214)
Round	-0.314*** (0.092)	-0.315*** (0.092)	-0.319*** (0.092)	-0.315*** (0.092)	-0.317*** (0.092)
Constant	13.433*** (3.051)	5.548 (7.424)	5.728 (7.370)	-3.768 (8.203)	-1.325 (7.652)
Demographics	✗	✓	✓	✓	✓
Matching group dummies	✓	✓	✓	✓	✓
Observations	1,122	1,122	1,122	1,122	1,122
Number of subjects	102	102	102	102	102
Left-censored obs.	261	261	261	261	261
Right-censored obs.	294	294	294	294	294
Wald $\chi^2$	154.7	163.2	164.4	175.7	212.3
Prob > $\chi^2$	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses, significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficients from random-effect tobit regression with individual contribution at round  $t$  as truncated dependent variable. All specifications include matching group dummies. Specifications 2-5 include information on participants' age, a dummy for being a student in Economics and gender interacted with being experienced in lab experiments (more than five prior experiments).

## Appendix C - Translated Instructions (Baseline)

Welcome to the experiment!

During the experiment you and the other participants will be asked to make several decisions. Please read the instructions carefully. Your decisions and those of the other participants will determine what you will gain from the experiment, what will be explained in detail below. Earnings in the experiment are expressed in experimental tokens. Two tokens correspond to 1 euro. In addition to what you gain in the experiment, you will receive a participation fee of 5 Euros.

From this moment on, any communication between participants is prohibited. If you do not respect this rule, you will be excluded from the experiment without any payment. Each participant will take individually and independently the same decision in each round of the experiment as will be explained below.

At the end of the experiment and before collecting your payment, you will have to answer a short questionnaire which will appear on your computer screen. Your answers will be anonymous and will be used only for research purposes.

### **The experiment**

The experiment consists of 30 rounds. In each round you will be interacting with two other partners, who will be newly and randomly selected from the participants of this experimental session. You can be sure to never interact with the same two other participants in two successive rounds.

In every round each participant is endowed with 20 tokens. Each participant can decide to either keep the tokens for herself (in part or entirely) or to contribute them to a common project with her selected partners. Specifically, you can contribute to this group project an amount  $c$  that can be 0, 5, 10, 15 or 20 tokens. This means that the difference between your total endowment and the contributed amount is how much you keep for yourself, i.e.  $20 - c$ . In every round you will be newly endowed with 20 tokens, which you can (in part or entirely) keep for yourself or contribute to the common project with the other two participants with whom you are interacting the given round.

The sum of the individual contributions by the three group members determines what the group project yields for each of the three group members. Their individual payoff from the project is given by the overall yield from the project divided by 3.

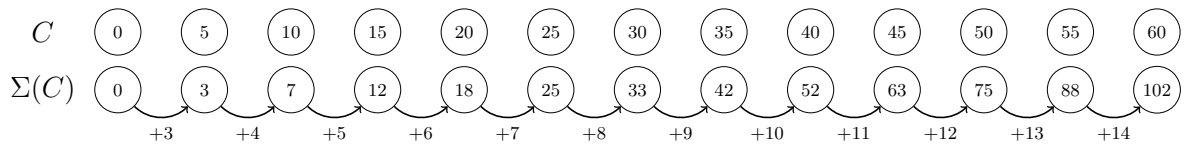
Since individual contributions vary by steps of 5 tokens, also the total contribution from the project, denoted by  $C$ , can vary only in steps of 5 tokens. In particular it can be equal to 0, 5, 10 etc. till 60 tokens.

The total yield from the project, which will be denoted as  $\Sigma(C)$ , is positive if at least one member of the group contribute to the project and it is 0 otherwise. Therefore  $\Sigma(C) = 0$  if  $C = 0$ . The first step of the total contribution yields 3 tokens, i.e.  $\Sigma(C) = 3$  if  $C = 5$ . The increase in yielding of the project in each successive steps is greater than that of the previous one. More in details, each successive step increases the yield of the project with one token more than the previous one.

Example: if the total contribution of the project increases from  $C = 5$  to  $C = 10$  the project yields 4 more tokens; if the total contribution increases from  $C = 10$  to  $C = 15$ , the project yields 5 more tokens and so on until the last possible increase of  $C$ , i.e. from  $C = 55$  to  $C = 60$ , when the project yield increases by 14 tokens.

The overall yielding from the project is given by the sum of its yields in each successive step: if  $C = 10$  then  $\Sigma(C) = 3 + 4 = 7$  tokens; if  $C = 15$  then  $\Sigma(C) = 3 + 4 + 5 = 12$  tokens; and so far until  $C = 60$  when  $\Sigma(C) = 102$  tokens.

The Table below shows what all the 5-step increases would yield in total for each of the three group members. In the first row you find the possible steps of total contribution,  $C$ , to the group project (from 0 to 60). The second row shows the overall yielding from the project,  $\Sigma(C)$ , corresponding to each step of total contribution (from 0 to 102).



The overall yield from the project will be divided equally among the members of the group, independently from their individual contribution. This means that each group member gets  $1/3$  of the earnings from the project, that is  $\Sigma(C)/3$  tokens.

Therefore, what you will earn in a given round depends on your contribution,  $c$ , and the sum of the three group members' contributions,  $C$ , and will be equal to:

$$20 - c + \Sigma(C)/3$$

If, as an example, in a given round you contribute 10 tokens to the project and none of



the other two members of your group contribute to it, your earning for that round will be  $20 - 10 + (7/3) = 12.33$ .

Do not worry, the computer will make all calculations!

### **Your payment**

At the end of the experiment the computer will randomly select one of the played rounds (each of them has the same probability to be selected) and your actual earnings for the experiment will correspond to the amount gained in that round. The earnings in tokens will be converted in Euros at the conversion rate of 2 tokens = 1 Euro and summed to your show up fee of 5 Euros.

## Appendix D - Translated Instructions (Milestone)

Welcome to the experiment!

During the experiment you and the other participants will make several decisions anonymously and independently. Please read the instructions carefully. Your decisions and those of the other participants will determine your gain for the experiment, as will be explained below. All communication between participants is prohibited during the experiment.

Earnings are expressed in experimental tokens and 2 tokens correspond to 1 Euro. In addition to the earnings from the experiment, you will receive 5 Euro as a participation fee. At the end of the experiment, and before collecting the earnings, you will have to answer an anonymous questionnaire on your computer screen.

### **The experiment**

The experiment consists of 12 rounds. In each round, you will interact in a group with two other participants chosen randomly from those present at the current session. Groups will be newly formed in each round, so that you will never be matched with the same two participants in two consecutive rounds.

At the beginning of each round, you will receive 20 tokens and can decide to keep them (some or all) for yourself, or to give them (some or all) as a contribution to a common project with the other two members of your group. Your contribution to the common project, denoted by  $b$ , can vary in steps of 5 tokens. Specifically, your contribution can be equal to 0, 5, 10, 15, or 20 tokens. The difference between your endowment of 20 tokens and your contribution is what you will keep for yourself.

In each round, you will not choose your contribution to the common project all at once, but you will determine it in four successive stages. In each step, you will be able to choose a contribution equal to 5 tokens or you can choose not to contribute at all, that is, you can choose a contribution equal to 0 tokens. At the end of each stage, you will be told the total contribution of the group, including yourself. In addition, you will be reminded how many tokens are left given your choices in previous phases, i.e., 20 tokens minus your total contribution up to that phase.

The total contribution to the project, denoted by  $C$ , is equal to the sum of the contributions of the three group members in the four stages. Since individual contributions vary in steps of 5 tokens, the total contribution also varies in steps of 5 tokens. Specifically, it can be equal to 0,

5, 10, etc. up to 60 tokens.

The total contribution to the project will determine the return of the project, denoted by  $R$ . The return of the project is positive only if at least one member of the group contributes to the project, otherwise it is 0. Therefore, if  $C = 0$ , then it will be  $R = 0$ .

Furthermore, the return of the project increases at an increasing rate as the total contribution increases. Therefore, each additional step results in a greater increase in the return of the project than the previous step. Specifically, the first 5-token step results in a return of 3 tokens, i.e.,  $R = 3$  if  $C = 5$ . For each additional step, the increase in the return of the project is one token greater than the increase due to the previous step: if  $C = 5 + 5 = 10$ , then  $R = 3 + 4 = 7$ ; if  $C = 5 + 5 + 5 = 15$ , then  $R = 3 + 4 + 5 = 12$ ; and so on until  $C = 60$ , which implies  $R = 102$ .

The return of the project will be divided equally among the three group members, so the per capita return of the project will be  $R/3$ . For your convenience, the table below shows the per capita return for each level of total contribution to the common project. Specifically, the first row shows the possible total contribution levels (from 0 to 60 tokens), while the second row shows the corresponding individual return (from 0 to 34 tokens).

Total contribution	0	5	10	15	20	25	30	35	40	45	50	55	60
Per capita total return	0	1	2,3	4	6	8,3	11	14	17,3	21	25	29,3	34

Overall, your earning in each round is:

$$20 - b + \frac{R}{3}$$

and, therefore, it depends on your contribution ( $b$ ) and the total contribution to the project ( $C$ ), as this determines the per capita return on the project ( $R/3$ ).

Before starting the experiment, you will have to answer some control questions related to the calculation of your earnings. However, you will not have to worry during the experiment: the computer will do all the calculations based on your choices!

### **Your payment for the experiment**

At the end of the experiment, the computer will randomly, and with equal probability, select one of the rounds. Your payment for the experiment will be equal to your earnings in that round, converted to euros at the rate of 2 tokens = 1 Euro, plus the participation fee of 5 Euro.