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Is regulation by milestones efficiency enhancing? An experimental study of environmental protection

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Is Regulation by Milestones Efficiency Enhancing?

– An Experimental Study of Environmental Protection –

JEL: C92, D78, H41, Q54.

Key Words: Cumulative Public Goods, Milestones, Climate Change, Experiment.

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Abstract

Viewing individual contributions as investments in emission reduction we rely on the familiar linear public goods-game to set global reduction targets which, if missed, imply that all payoffs are destroyed with a certain probability. Regulation by milestones does not only impose a final reduction target but also intermediate ones. In our leading example the regulating agency is Mother Nature but our analysis can, of course, be applied to other regulating agencies as well. We are mainly testing for milestone effects by varying the size of milestones in addition to changing the marginal productivity of individual contributions and the probability to lose.

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1 Introduction

In real life, a number of long-term projects rely on interim targets or milestones. For individual choice problems imposing additional constraints may be detrimental for efficiency. External regulation does not make much sense if individuals can cope with problems on their own. However, this is different for collective choice problems. In the economic domain we, indeed, observe milestones in social contexts mainly. For instance, governments often announce official targets for budget reductions. Another very prominent example is the GATT with its aim of constant liberalization of international trade, a goal which cannot be easily operationalized. Nevertheless, interim targets have been regularly set in trade rounds. At the end of each round, the negotiating parties agreed on an agenda to stepwise reduce barriers to trade within a certain period.

A third example is environmental conservation. Here investments in climate protection could be imposed by an international environmental agreement (cf. Barrett 1994, 2003). It often includes a long term final target which should be reached at a certain date, e.g. reduction of total emissions until 2050 by about 50 per cent based on the 1990 emissions (IPCC 2007).[1] In such a situation milestones can proxy intermediate abatement targets to keep total emissions below a critical threshold (e.g. the emission reduction targets in the context of the Kyoto-protocol). If the international community fails to approach these intermediate targets it gets more difficult to reach the final threshold which then renders catastrophic events more likely.

The rationale for such milestones is to increase the intermediate credibility of policy announcement through commitment to testable intermediate goals. Thereby, the government may overcome pressure from vested interests and measure a long term oriented goal achievement by short term achievements. The three examples illustrate that often milestones are seen as disciplining factors for policy makers. In global economic policy making, the evidence seems clear - GATT has achieved some considerable progress with international comprehensive liberalization. Thus applying a similar tool to climate policy may also seem reasonable.

However, there is neither convincing empirical evidence nor a sound theoretical basis in the global governance literature and, more specifically, how to promote efficiency by imposing additional restrictions like milestones. What we find is evidence for markets, such as labor markets. Falk and Kosfeld (2006), for instance, have provided evidence showing that an employer may suffer from imposing a minimum performance threshold for her employees. Similarly, Berninghaus et al. (2008) found

[1] Without national commitments ("the business as usual" scenario) estimations predict an temperature increase with possibly catastrophic consequences (Stern 2007, Latif 2010).

that downward wage flexibility, if exploited, may inspire shirking. In a quite general sense, we will add to this literature, but not in an one-off interaction but in a recursive interaction task.

What we consider is a recursive game where all players can gain by reaching a certain final common target. The situation can, however, be more strictly regulated by imposing intermediate targets to be reached earlier. Thus, what regulation does is imposing additional risks of failure. Our main milestone hypothesis predicts that additional regulation via milestones, i.e. intermediate performance targets, is efficiency enhancing.

Although our leading example is environmental protection to prevent global warming, we have abstained from inventing a novel game and have tested the milestone hypothesis with a familiar experimental workhorse to compare our findings to those of other experiments. More specifically, we have used the familiar linear public goods game (see Ledyard 1995, for an early survey of experimental studies) by interpreting contributions as investments protecting the environment, e.g. investments in emission reduction to limit or prevent global warming.

Thus, milestones and contribution targets set lower bounds for emission reduction. If one of the milestones or the final goal is missed, the rather dramatic effect is that all players lose everything (all of their payoff) with a given probability. This implies additional (subgame perfect) equilibria to the usual free-riding equilibrium where the sums of the contributions so far exactly hit the targets.

We test the milestone hypothesis as treatment effects with milestones as one treatment variable. Whereas for all treatments the final target is the same we distinguish between high milestones (H) and much lower ones (L), the latter rendering the milestones rather inessential. We compare the H versus L – effects in three different scenarios leading to 2x3=6 different treatments. The three scenarios vary the individual marginal productivity of contributions and the probability of losing everything if one of the targets is not met.

In spite of the impressive tradition of public goods experiments (Ledyard 1995) there are only few studies with focus on environmental protection. Milinski et al. (2008) introduce and experimentally analyze a collective-risk social dilemma, framed as dangerous climate change. The players were endowed with €40 each and could continuously contribute €0, €2, or €4 to a "climate change account" over ten rounds. If subjects failed to reach the threshold after the last round, they lost everything left with a probability of 90%, 50% or 10%, respectively. Results show that even with a losing probability of 90% half of the groups failed to reach the threshold.

Fischbacher et al. (2010) rely on a linear public goods-game, however, with only

one trial contribution target with rather similar effects, but do not address at all the question whether milestones would be efficiency enhancing. They, on the other hand, made their final target stochastic by assuming that players receive either private or common stochastic signals whose sum determines the final target. We will compare our findings with earlier related ones in the concluding section.

Section 2 describes our experimental design, including all treatments and the experimental protocol. In section 3 we present our results. Conclusions in section 4 round off the paper.

2 Experimental Design

2.1 General Setting

To capture environmental protection problems, e.g. avoiding global warming, we rely on a linear public goods game (Isaac et al. 1985) as our experimental workhorse. Thus monetary contributions mean to invest in emission reduction for the sake of less global warming whereas "free-riding" stands for voluntarily abstaining from any individual attempt to protect the environment.

In all treatments five players, respectively participants $i = 1, \ldots, 5$, are endowed with $e = 65$ tokens which they can either keep or repeatedly contribute over six periods $t = 1, \ldots, 6$. Individual contributions $c_{i,t}$ must satisfy $0 \leq c_{i,t} \leq 10$ guaranteeing that after six periods each participant has something left. In all treatments, furthermore, all players i lose everything, i.e. what they have kept for themselves and what they could gain from accumulated contributions $C^6 = \sum_{t=1}^{6} \sum_{i=1}^{5} c_{i,t}$ by all five players, with a certain probability $p \in (0, 1)$ if the contribution target of $C_6 = 150$ tokens is not reached $(C^6 < C_6)$. Assuming constant individual marginal productivity ($\alpha \geq 0.2$) of individual contributions $c_{i,t}$ the payoffs for players $i = 1, \ldots, 5$ are thus

$$U_i = \begin{cases} e - \sum\limits_{t=1}^{6} c_{i,t} + \alpha C^6 & \text{for} \quad C^6 \geq 150 \\ (1-p)(e - \sum\limits_{t=1}^{6} c_{i,t} + \alpha C^6) & \text{if} \quad C^6 < 150. \end{cases}$$

Under the condition that $\alpha < 1 \leq 5\alpha$ opportunism in the sense of own monetary payoff concerns suggests to reduce the own contributions in both ranges $C^6 < C_6$ and $C^6 > C_6$, as long as this does not mean that C^6 becomes smaller than C_6, whereas $\alpha > 0.2$ renders maximal individual contributions as efficient (in the sense of payoff maximization). Due to the discontinuity of the payoff function U_i at C_6 there exist

many strict, but only two symmetric and strict equilibria leading to results

$$E^0 = \left[\sum_{t=1}^{6} c_{i,t}^0 = 0 \quad \text{for} \quad i = 1, \ldots, 5\right] \text{and} \left[\sum_{t=1}^{6} c_{i,t}^* = 30 \quad \text{for} \quad i = 1, \ldots, 5\right] = E^*,$$

respectively.

These together with the efficiency outcome with $\sum_{t=1}^{6} c_{i,t}^+ = 60$ for $i = 1, \ldots, 5$ serve as our benchmarks when discussing actual behavior.[2] Since in case of E^0 no individual player i can guarantee that the target of 150 is reached, it is obvious that E^0, based on 0-contributions throughout, is a (subgame-perfect) equilibrium. For E^* this holds, too, since increasing $\sum_{t=1}^{6} c_{i,t}$ above 30 is clearly suboptimal and contributing less than 30 would yield maximally 65 but only with probability p whereas one's payoff from E^* is $U_i = 150\alpha + 35$ which is at least 65 due to $\alpha \geq 0.2$.

Note that the target C_6 could already be reached within three periods by all five players contributing maximally ($c_{i,t} = 10$) in each of the three periods. Thus viewing the first three periods as a base game with already two strict (symmetric) equilibria reveals that "finite horizon-Folk Theorems" (Benoit and Krishna 1987) can be applied showing that there exists also non-stationary pure strategy (subgame perfect) equlibria.

In all treatments subjects receive periodic feedback information, i.e. after each period $t = 1, \ldots, 6$ all five players $i = 1, \ldots, 5$ learn about the individual contributions $c_{j,t}$ of all players $j = 1, \ldots, 5$ and thus can react to such feedback information when deciding on their next contribution $c_{i,t+1}$. Obviously, this allows for reciprocity and all sorts of disciplining actions by future dealings on which the so called Folk-Theorems are based (Aumann 1981, Axelrod and Dion 1988, Benoit and Krishna 1985).

2.2 Milestones

Regulation is implemented by means of milestones (M), i.e. contribution targets on the way of reaching the final target of $C_6 = 150$, namely C_2 after period 2 and C_4 after period 4. Not reaching the intermediate targets has the same consequences as not reaching C_6. Although players $i = 1, \ldots, 5$ can already lose everything after period 2 and 4, they will in the experiment first decide successively for all six periods $t = 1, \ldots, 6$. Only then it will be decided randomly in view of C^2, C^4 and C^6 whether or not they lose everything already after period 2, if $C^2 < C_2$, after period 4 if $C^4 < C_4$, or finally if $C^6 < 150$.

[2] To be clear the efficiency benchmark requires $\alpha > 0.2$.

Introducing these milestones changes the payoff function to,

$$U_i^M = \begin{cases} e - \sum_{t=1}^{6} c_{i,t} + \alpha C^6 & \text{if} \quad C^2 \geq C_2 \,\&\, C^4 \geq C_4 \,\&\, C^6 \geq C_6, \\ (1-p)(e - \sum_{t=1}^{6} c_{i,t} + \alpha C^6) & \text{if} \begin{cases} C^2 < C_2 \,\&\, \geq \text{for the other} \\ \text{two restrictions} \quad \text{or} \\ C^4 < C_4 \,\&\, \geq \text{for the other} \\ \text{two restrictions} \quad \text{or} \\ C^6 < C_6 \,\&\, \geq \text{for the other} \\ \text{two restrictions,} \end{cases} \\ ((1-p) + (1-p)^2)(e - \sum_{t=1}^{6} c_{i,t} + \alpha C^6) & \text{if} \begin{cases} C^2 < C_2 \,\&\, C^4 < C_4 \,\&\, C^6 \geq C_6 \\ \text{or} \\ C^2 < C_2 \,\&\, C^6 < C_6 \,\&\, C^4 \geq C_4 \\ \text{or} \\ C^4 < C_4 \,\&\, C^6 < C_6 \,\&\, C^2 \geq C_2, \end{cases} \\ ((1-p) + (1-p)^2 + (1-p)^3))(e - \sum_{t=1}^{6} c_{i,t} + \alpha C^6) & \text{otherwise,} \end{cases}$$

where $C^2 = \sum_{t=1}^{2} \sum_{j=1}^{5} c_{j,t}$ and $C^4 = \sum_{t=1}^{4} \sum_{j=1}^{5} c_{j,t}$. Comparing U_i with U_i^M clearly reveals that implementing milestones on a sufficiently high level implements "regulation" where, in view of the environmental interpretation, the regulator is Mother Nature. We predict a milestones effect, i.e. more efficient performance with stricter milestones. In order to test the milestones-effect we distinguish two cases:

1. strict milestones (H): $C_2 = 50$ and $C_4 = 100$, and
2. less strict milestones (L): $C_2 = 5$ and $C_4 = 10$.

For the case of "strict milestones" (H) we set the intermediate targets such that necessary contributions to reach the final target of C_6 increase linearly. In the less strict case, we do not omit the milestones, but lower them by a factor of 10 what should render them inessential, such that payoff U_i^M approximates U_i. The "philosophy" of such a manipulation is, of course, that the two cases H and L rely on the same verbal instructions and differ only in two numerical parameters, namely C_2 and C_4, what should induce no difference in (sub)conscious demand effects between H and L where "L" stands for –actually very– "low milestones".

2.3 Scenarios

We consider three different scenarios to test the potential milestone effect by comparing treatments with strict (H) and low milestones (L).

In the baseline scenario (B) we set $\alpha = 0.4$ and $p = 0.5$ in combination with the group size of 5.[3] Since the probability of losing everything seriously increases the free-riding "disincentives", the efficiency benchmark, $\sum_{t=1}^{6} c_{i,t}^{+} = 60 \quad \text{for} \quad i = 1, \ldots, 5$ maybe expected more often than in usual public goods experiments.

Our experimental design could be criticized since linearly increasing total payoffs, even above the final target, may not adequately capture environmental conservation. We therefore propose an alternative scenario (S) in which reaching the final target C_6 just conserves the status quo, i.e. a mean payoff of 65 tokens, and overshooting is not beneficial at all, i.e. by removing the efficiency of $C^6 > C_6$. This is done by lowering the constant individual marginal productivity to $\alpha = 0.2$. Of course, compared to scenario B incentives to cooperate are also smaller below C_6.

This manipulation changes two aspects: it questions the efficiency benchmark and reduces the free-riding "disincentives" as measured by the expected payoff of a unilateral deviation from the E^*-equilibrium to constant 0-contributions (free-riding). The difference in expected payoffs between the E^*-equilibrium and the payoff of a unilateral deviation to constant 0-contributions for scenario B is $95 - 56.5 = 38.5$ tokens, whereas it is 20.5 tokens for scenario S only. Since by comparing these scenarios the two effects, mentioned above, cannot be disentangled we consider a third scenario (P) and preserve the equilibrium and efficiency benchmarks of the baseline scenario by setting $\alpha = 0.4$, but keeping the free-riding "disincentive" equal to that of scenario (S) via lowering the probability of losing everything from $p = 1/2$ to $1/3$.[4] Altogether this $2X3$ factorial design results in six treatments as listed in table 1.

2.4 Experimental Protocol

We ran 12 separate sessions for the six treatments. 360 student participants were recruited from various disciplines of Jena university using the ORSEE software (Greiner 2004). The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007). In each session the 30 participants were subdivided in two equally large matching groups of participants playing the 6 period-recursive games repeat-

[3] One might argue that setting $\alpha = 0.4$ is unrealistic in a climate change setting, since investments in emission reduction are usually seen as preserving the status quo. This is because sustainability is the main argument for policy intervention.

[4] The probability is calculated by comparing the individual payoff that results when all players $i = 1, \ldots, 5$ play E^* to the individual payoff that results for the player who deviates from E^* by free-riding: $(95 - 20.5) = (1 - p)(65 + 0.4x120)$, implying $p = 38.5/113 \approx 1/3$.

Table 1: $2x3$-factorial treatment design

		Milestones	
		H	L
P	$\alpha = 0.4; p = 1/3$	PH	PL
B	$\alpha = 0.4; p = 1/2$	BH	BL
S	$\alpha = 0.2; p = 1/2$	SH	SL

edly. After each play of the 6 period-recursive game the 15 participants of a matching group were randomly rematched to form three new groups with five players each who would interact in the next round of play. Since participants were only told that they are randomly rematched, they should have expected that each of the 29 other participants can become an interaction partner. This should even more have discouraged reputation effects (participants can, of course, try to establish some reputation within the same rounds, i.e., across the six periods of a given round).

After entering the computer laboratory of the Max Planck Institute in Jena participants received written instructions (see App. C for translated materials) which were also read aloud to establish their common knowledge. After answering questions privately participants had to answer a few control questions. The experiment only started when all participants had answered all control questions correctly. A session with altogether 12 rounds needed on average 90 minutes, including reading instructions, answering control questions and payment. Average earnings were €17 with minimum €2.5, and maximum €29, including the €2.5, show-up fee.

3 Results

We describe our findings first at the group level with a closer look at individual behavior afterwards. We do so by first stating "Results" and then trying to justify them by descriptive and statistical data analysis.

RESULT 1: Equilibrium play E^* and E^0 is negligible.

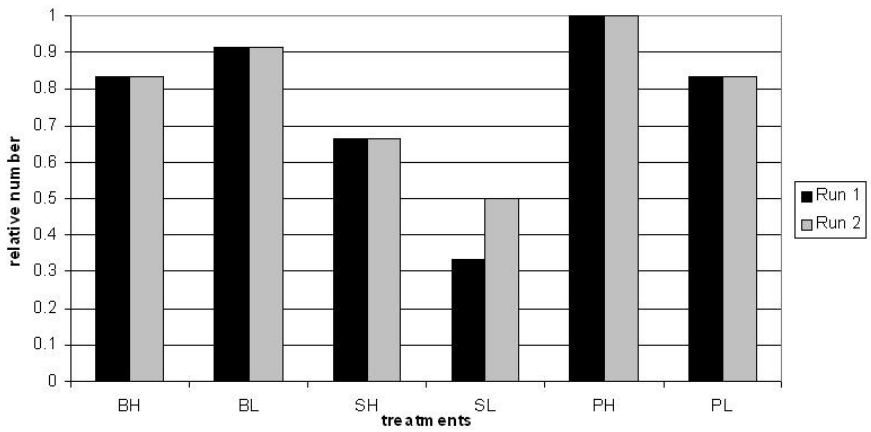
Only 3 out of 144 groups end up in the E^* outcome of investing 150 tokens in total (2 groups in treatment SH and one in treatment SL). One group in treatment SL was able to coordinate on the fair share equilibrium of contributing 5 tokens each round. No groups totally freeride or contribute the maximum possible. However, we are not really interested in testing equilibrium outcomes but rather want to study treatment

effects. Let us now turn to our main question is whether regulation by milestones is efficiency enhancing.

RESULT 2: Depending on the scenario, milestones increase the probability of reaching the final target.

Since expected payoffs when not reaching the final target are less than when reaching it, in all scenarios it is more efficient to meet the final target. Figure 1 shows the probability of reaching the final target, separated by scenario and treatment. In scenario B and P almost all groups succeeded (10 of 12) and there is no significant treatment effect (H versus L). The picture slightly changes for scenario S with an almost significant milestones effect for the success probability in the first run, where 8 versus 4 out of 12 groups reached the final target (Fisher's exact, $p = 0.110$). However, the effect disappears since after the restart more groups, namely 6, succeeded in SL whereas for SH there is no change (Fisher's exact, $p = 0.340$).

Figure 1: Final target reached



RESULT 3: On the group level milestones increase average group contributions only in scenario S.

Figure 2 depicts separately for the three scenarios (scenario B on top, scenario S in the middle and scenario P at the bottom) and treatments average contributions over the sequence of play, i.e. the six rounds of two runs. In the first run of scenario B average contributions are lower in the treatment with strict milestones (5.6 tokens versus 5.98 tokens) and it seems that imposing additional risks by intermediate tar-

gets is detrimental for efficiency. The effect is, however, not statistically significant (Mann-Whitney-U, $p = 0.2142$). For scenario S a significant milestones effect shows up in the first run. Imposing milestones increases contributions by approximately 30 per cent from 3.78 to 4.93 tokens (Mann-Whitney, $p = 0.0831$) and is, hence, enhancing efficiency. No significant difference between treatments shows up in scenario P and, moreover, in all three scenarios after the restart.

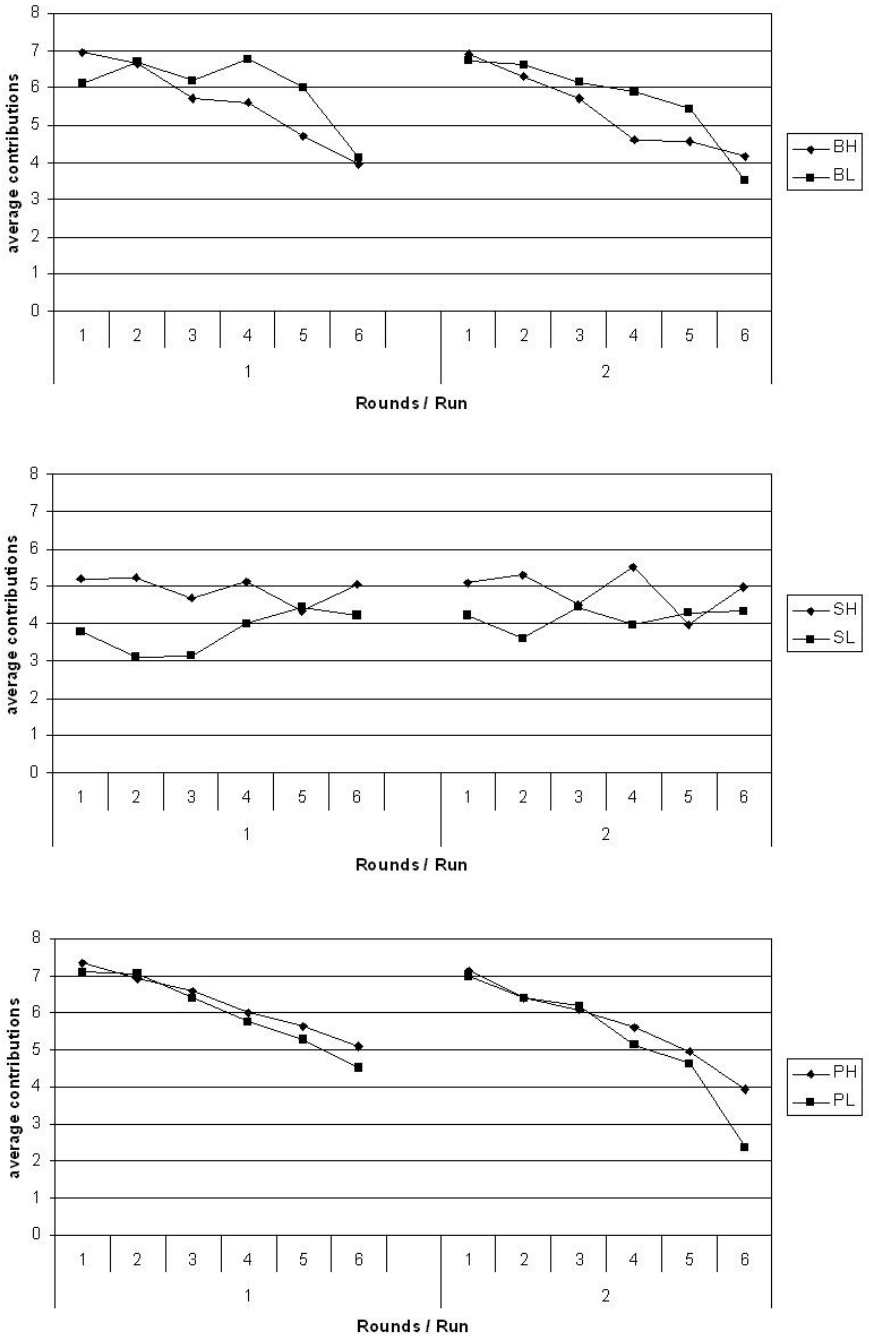
Thus, milestones increase the probability of success and contributions only in scenario S, which features investments into emission reduction as conserving the status quo by ruling out efficiency enhancement below and above C_6.

RESULT 4: Analyzing individual contributions, milestones are inspiring them in scenario S and P.

Thus, on the level of individual behavior by using panel regressions, the picture for scenario P changes. The panel is by design strongly balanced and consists of 60 subjects per treatment cell (120 subjects per scenario). Taking group heterogeneity into account we make use of a panel regression with adjusted standard errors on the group level (each group is one cluster), e.i., in total 24 groups per treatment (48 groups per scenario). Moreover, there exist 24 groups for each run and 48 groups for both runs together. Contributions are explained by a dummy for the treatment with strict milestones (PH), dummies for one session of the respective treatments (S_{PH} and S_{PL}), lagged variables on own contribution, average contribution within the group and accumulated contributions. Regression results are shown in table 2. There are no significant treatment effects in the first run (the first two columns). However, in columns three and four showing regression results for the sequence after the restart (second run), the treatment dummy is positive and significant. Controlling for sessions only (column 3) the effect is significant at the 5 per cent level. Additionally controlling for various forms of information which subjects get (column 4) results in a better fit and a significant treatment effect on the 1 per cent level, however, lower in magnitude. More precisely, subjects contribute on average 0.766 tokens more to the public good with strict than with less strict milestones. Taking the two runs together in column 5 and controlling for the restart (including a dummy), the effect is weaker (on average 0.457 tokens more in SH) but still significant at the 5 per cent level, whereas the restart dummy has no significant effect.

The effect is stronger in scenario S (see table 3). Although, we do not find a significant treatment effect after the restart, there is a strong and high effect in the first run.

Figure 2: Average contribution per treatment



Individuals in treatment SH contribute on average 1.080 tokens more with strict milestones, when controlling for the received information (column 2). In contrast to scenario P the milestones effect disappears after the restart (columns 3-4), but is present when considering both runs, controlling for information and the restart (column 5). Subjects in treatment SH contribute on average 0.873 tokens more than in SL, whereas

the restart dummy is insignificant. Individual level analysis gives no further insights for scenario B (see appendix A).

Table 2: OLS Panelregression with clustered standard errors on group level for scenario P

	run 1 contribution	run 1 contribution	run2 contribution	run 2 contribution	both runs contribution
PH	0.872	0.160	1.261*	0.766**	0.457*
	(1.46)	(0.65)	(2.53)	(2.93)	(2.46)
S_{PH}	-0.294	0.308	-0.372	-0.00931	-0.0242
	(-0.36)	(1.07)	(-1.59)	(-0.06)	(-0.13)
S_{PL}	0.956	0.403	1.350*	0.758**	0.483
	(1.18)	(1.02)	(2.29)	(2.83)	(1.68)
lag contribution		0.479***		0.479***	0.426***
		(7.00)		(8.04)	(10.08)
lag average contr.		0.320**		0.109	0.171*
		(3.26)		(1.01)	(2.17)
lag accumulated		-0.00715*		-0.0164***	-0.000674
		(-2.56)		(-4.77)	(-0.34)
restart					-0.0471
					(-0.29)
cons	5.533***	1.267**	4.606***	2.650**	1.824***
	(19.27)	(3.09)	(9.97)	(2.92)	(3.97)
N	720	600	720	600	1320
$N_{Indiv.}$	120	120	120	120	120
R^2_O	0.0102	0.333	0.0193	0.301	0.227

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Although the non-parametric group level analysis suggests no milestone effect in scenario P, we do find a significant milestones effect on the individual level controlling for group, session and information effects. Compared to scenario S the effect is smaller in magnitude and less significant. The milestones effect is therefore not only driven by excluding efficiency above and below targets (scenario S), but also due to higher free-riding "disincentives" (scenario P and S).

RESULT 5: The milestones effect in scenario S and P is mainly driven by a higher share of individual contributions between 4 and 6 tokens.

To further scrutinize contributions on the individual level as well as the general sequence of play we have classified contributions into *low* (0-3 tokens), *medium* (4-6 tokens) and *high* (7-10 tokens). Figure 3 shows the resulting relative number of contri-

Table 3: OLS Panelregression with clustered standard errors on group level for scenario S

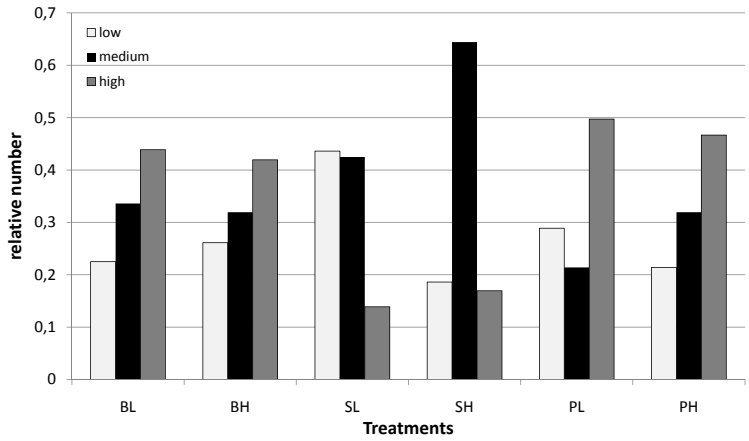
	run 1 contribution	run 1 contribution	run 2 contribution	run 2 contribution	both runs contribution
SH	2.156***	1.080*	1.000	0.473	0.873*
	(3.90)	(2.32)	(1.60)	(0.86)	(2.21)
S_{SH}	-0.100	-0.128	0.333	0.359	0.0898
	(-0.38)	(-0.93)	(1.07)	(1.52)	(0.58)
S_{SL}	1.917**	1.286*	0.844	0.538	0.850*
	(2.82)	(2.56)	(1.32)	(1.08)	(2.15)
lag contribution		0.343***		0.387***	0.333***
		(3.68)		(4.74)	(5.75)
lag average contr.		0.0874		-0.0340	-0.0196
		(0.51)		(-0.17)	(-0.16)
lag accumulated		0.00925**		0.00530	0.00556*
		(2.73)		(1.44)	(2.55)
restart					0.0416
					(0.21)
cons	2.822***	1.052*	3.717***	2.079**	1.949***
	(5.36)	(2.41)	(6.87)	(2.78)	(4.85)
N	720	600	720	600	1320
$N_{Indiv.}$	120	120	120	120	120
r^2_O	0.100	0.232	0.0363	0.165	0.171

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

butions for the respective classes in the six treatments in the first run.[5] It shows that contributions are quite heterogeneous. However, in treatment SH most contributions (64.44 per cent) fall into the *medium* category. Compared to treatment SL, milestones seem to discipline subjects to stay on the track to the final target as the number of *low* contributions is significantly lower (Fisher's exact, $p = 0.000$) and *medium* contributions are significantly more frequent (Fisher's exact, $p = 0.000$). A similar but not that strong pattern is found for scenario P in which we find a significantly lower frequency of *low* contributions and a significantly higher frequency of *medium* contributions in treatment PH (Fisher's exact, $p = 0.025$ for *low* and $p = 0.002$ for *medium*). No significant difference between contribution classes is found in scenario B (see also the graphical illustration in figure 3). The share of contributions classified as *high* in scenario S is significantly lower than those in scenario B and P (Fischer's exact, $p = 0.000$, for BL vs. SL, BH vs. SH, PL vs. SL and PH vs. SH), whereas we do not find any significant difference between B and P.

[5] In the following we show results for the first run only. For the second run, the qualitative results for the classificationare the same.

Figure 3: Contribution classes for B, S and P



RESULT 6: Milestones stabilize individual behavior over the sequence of play in scenario S and P.

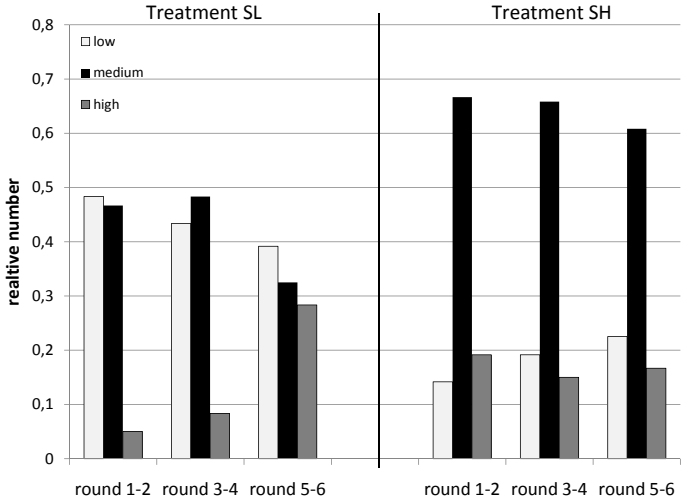
Is the classified behavior stable over the sequence of play? To answer this we have, in addition to the classification above, further subclassified the relative number of contributions into three phases of rounds: *round 1-2* , *round 3-4* and *round 5-6*.[6]

The results of the classification in scenario S are separately shown for the two treatments (SL and SH) in figure 4. There is a relatively stable share of *low* contributions in treatment SL over the three phases (Kruskall-Wallis, $p = 0.3588$), which is significantly higher than in SH (Fisher's exact, $p = 0.000$ for *round 1-2* as well as *round 3-4* and $p = 0.004$ for *round 5-6*). In contrast, a high and stable share of *medium* contributions is found in treatment SH (Kruskall-Wallis, $p = 0.5946$), which is in all three phases significantly higher than in SL (Fisher's exact, $p = 0.000$ for *round 1-2* , $p = 0.001$ for *round 3-4* and $p = 0.004$ for *round 5-6*). Thus the disciplining effect of the milestones operates through *medium* contributions, i.e. subjects seem to coordinate on medium contributions throughout. Subjects in treatment SL try to make the best out of a bad job in *round 5-6*, with significantly more contributions in the *high* class than in the previous rounds (Fisher's exact, $p = 0.000$). However, as shown in figure 1

[6]We choose this classification to capture differences in play between rounds including a target. Moreover, results qualitatively do not change if we take every single round into account.

above, they often fail to reach the long-term target. The comparison between SL and SH over the sequence of play shows that milestones stabilize average contributions and thereby offer some intermediate planning reliability.

Figure 4: Contribution classes over treatments and rounds for S

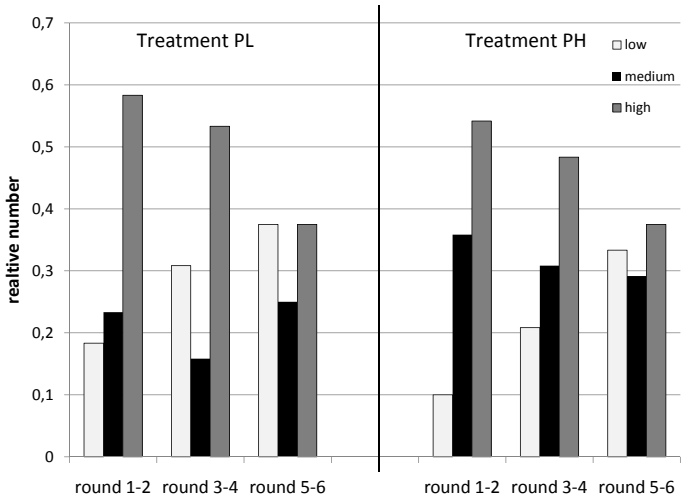


In Scenario P (see figure 5) milestones have a significant disciplining effect especially in the first and second phase. The share of *low* contributions for PH is significantly lower than for PL (Fisher's exact, $p = 0.047$ for *round 1-2* and $p = 0.052$ for *round 3-4*). However, low contributions in both treatments increase steadily indicating that participants anticipate that total contributions will exceed the critical thresholds. We also observe differences for the contribution class labeled as *medium*. In pase 1 and 2 *medium* contributions in treatment PH are significantly higher than in treatment PL (Fisher's exact, $p = 0.024$ for *round 1-2* and $p = 0.005$ for *round 3-4*). The finding indicates that the milestones effect – as in scenario S – is driven by *low* and *medium* contributions. The overall contribution patterns for both treatments (beside the differences mentioned above) look very similar.

4 Conclusion

To investigate if regulation by milestones - intermediate targets on the way to a long term target - is efficiency enhancing we have imposed additional risks of failure on the way to the long-term target. In the threshold public goods game featuring a final

Figure 5: Contribution classes over treatments and rounds for P



target after six rounds not reaching the final target leads to a loss of everything with a given probability. The same consequences are assumed to occur if a milestone is not reached. Treatments vary the magnitude of the milestones from less strict (approximately inessential) to strict milestones (essential) and the marginal productivity of contributions and thereby efficiency and free-riding incentives as well as the probability of loosing everything in case of failures.

We find substantial differences between the three scenarios. Milestones do have a positive impact on efficiency when there is no efficiency benchmark and free-riding "disincentives" are low. The effect is strongest when higher contributions below and above targets are not efficiency enhancing and free-riding "disincentives" are low, so that investments into emission reduction can only preserve the "status quo". A moderate effect is found when efficiency can be promoted but free-riding "disincentives" are still low. However, the result is mainly due to second run behavior. Since in the context of climate change, there may not be a restart or a second chance, learning may be too late. In the scenario with efficiency and low incentives to free-ride no milestones effect is found.

Our results are similar to Milinski et al. (2008) finding that half of the groups have difficulties in reaching the final target. Note that they frame the game as climate change what might have increased contributions. Comparing our findings to Fischbacher et al. (2010) who do not implement at all intermediate targets we confirm

their result that more serious losses when missing the threshold promotes cooperation. It is interesting that commonly known targets (their common signal case), which we have implemented in a deterministic way, seems to provide a best case scenario for environmental protection. These and our observations imply that regulation by milestones, depending on the specific scenario, can be efficiency enhancing.

One should be cautious when generalizing our conclusions. Since we do not capture advantages of early investments, our situation is kind of a worst case scenario for testing the milestone hypothesis. In the case of environmental protection early investments can be seen as superior to late investments. Without early investments the costs of climate conservation may increase because emissions accumulate and reaching a certain emission reduction target becomes more difficult (cf. Kemfert 2005). Moreover, environmental returns might need some time to develop and to accumulate. It was not the scope of this paper to capture it but would be interesting topics of future research.

Here, we implemented and manipulated milestones exogenously. This seems unrealistic when thinking of environmental agreements in which milestones are usually negotiated as done in Kyoto. Implementing endogenous milestones in such a setting is tricky as it can not be based on punishments of Mother Nature. To do so, one has to think of the consequences if a milestone is missed.

In the actual debate on climate change, discussing the investments into emission reduction needed to preserve the long-term climate, milestones may be essential to overcome the actual coordination problem. Intermediate targets, as proposed by international environmental agreements like Kyoto, might help to solve the problem. However, our results reveal a high risk of failure. This has to be kept in mind when hoping for the milestone effects, especially when discussing coordination problems with possibly catastrophic consequences. In our scenario milestones provide a punishment mechanism, imposed by nature, which is in reality may be lacking so far and whose implementation by international agreements may be very problematic but could be very helpful nevertheless.

References

Aumann, R.: 1981, Survey of repeated games, Bibliographisches Institut, Mannheim/Wien/Zürich, pp. 11–42.

Axelrod, R. and Dion, D.: 1988, The further evolution of cooperation, *Science* **242**(4884), 1385–1385.

Barrett, S.: 1994, Strategic environmental policy and international trade, *Journal of Public Economics,* **Vol. 54**, pp. 325–338.

Barrett, S.: 2003, *Environment and statecraft*, Oxford University Press Oxford.

Benoit, J. and Krishna, V.: 1985, Finitely repeated games, *Econometrica: Journal of the Econometric Society* **53**(4), 905–922.

Benoit, J. and Krishna, V.: 1987, Nash equilibria of finitely repeated games, *International Journal of Game Theory* **Vol. 16(3)**, pp. 197–204.

Berninghaus, S., Bleich, S. and Güth, W.: 2008, Wage Flexibility in Ongoing Employment Relations - An Experiment with a Stochastic Labor Market, *in* W. Franz, H. Ramser and M.Stadler (eds), *Schriftenreihe des Wirtschaftswissenschaftlichen Seminars Ottobeuren*, Mohr Siebeck, Tübingen, pp. 171–192, Vol.37.

Falk, A. and Kosfeld, M.: 2006, The Hidden Costs of Control, *The American economic review* **Vol. 96(5)**, pp. 1611–1630.

Fischbacher, U.: 2007, z-Tree: Zurich toolbox for ready-made economic experiments, *Experimental Economics* **10**(2), 171–178.

Fischbacher, U., Güth, W. and Levati, V. M.: 2010, Crossing the point of no return: a public goods experiment (mimeo).

Greiner, B.: 2004, The online recruitment system orsee 2.0 - a guide for the organization of experiments in economics, *mimeo*, Department of Economics, University of Cologne.

IPCC: 2007, *International Panel on Climate Change, 30 April-4 May 2007: Mitigation of Climate Change – Summary for Policymakers*. <http://www.ipcc.ch/SPM040507.pdf>.

Isaac, R., McCue, K. and Plott, C.: 1985, Public goods provision in an experimental environment, *Journal of Public Economics* **Vol. 26(1)**, pp. 51–74.

Kemfert, C.: 2005, Weltweiter Klimaschutz - Sofortiges Handeln spart hohe Kosten, *DIW-Wochenbericht* **72**(12-13), 209–215.

Latif, M.: 2010, Die Herausforderung globaler Klimawandel, *Perspektiven der Wirtschaftspolitik* **Vol. 11 (s1)**, pp. 4–12.

Ledyard, J. O.: 1995, Public Goods: A Survey of Experimental Research, *in* J. H. Kagel and A. E. Roth (eds), *The Handbook of Experimental Economics*, Princeton University Press, Princeton, New York, pp. 111–194.

Milinski, M., Sommerfeld, R. D., Krambeck, H.-J., Reed, F. A. and Marotzke, J.: 2008, The collective-risk social dilemma and the prevention of simulated dangerous climate change, *Proceedings of the National Academy of Sciences* **Vol. 105(7)**, pp. 2291.

Stern, N.: 2007, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge, New York.

A Panel Regressions

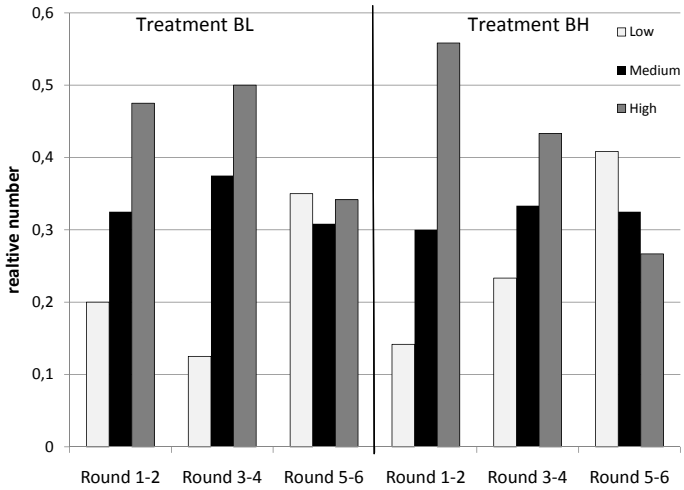
Table 4: OLS Panelregression with clustered standard errors on group level for scenario B

	(1) contribution	(2) contribution	(3) contribution	(4) contribution	(5) contribution
BH	-0.367	-0.206	-0.400	-0.262	-0.315
	(-0.66)	(-0.46)	(-1.94)	(-1.52)	(-1.40)
S_{BH}	-0.111	-0.187	-0.0389	0.0564	-0.0731
	(-0.22)	(-0.48)	(-0.20)	(0.33)	(-0.35)
S_{BL}	-0.0889	0.186	-0.133	-0.0141	-0.0639
	(-0.19)	(0.56)	(-0.21)	(-0.03)	(-0.21)
lag contribution		0.371***		0.284***	0.294***
		(5.61)		(3.81)	(5.93)
lag average contr.		0.213		0.263	0.0878
		(1.69)		(1.94)	(1.02)
lag accumulated		-0.0142***		-0.0137***	-0.00495*
		(-4.52)		(-3.70)	(-2.13)
restart					0.181
					(0.98)
cons	6.022***	3.509***	5.794***	3.466***	3.956***
	(22.54)	(3.89)	(31.86)	(3.99)	(7.03)
N	720	600	720	600	1320
$N_{Indiv.}$	120	120	120	120	120
r^2_O	0.00341	0.214	0.00324	0.189	0.115

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

B Contribution classes over rounds

Figure 6: Contribution classes over treatments and rounds for B



C Instructions (English translation for treatment BH)

Welcome and thank you for participating in this experiment! Please read these instructions, which are identical for all participants, carefully. For your arrival in time you receive a show-up fee of €2.50. In the following experiment you will earn additional money, depending on your decisions and the decisions of other participants. During the course of the experiment, all amounts are stated in ECU (experimental currency units). At the end of the experiment all earned ECU will be converted in cash and privately paid according to the following exchange rate:

$$1ECU = 0.10€.$$

From now on, please do not talk to your neighbors, switch of your cell phone, and remove unnecessary things from your desk. It is important that you follow those rules - otherwise we have to exclude you from the experiment and any compensation. In case you have a question, please raise your hand and we will answer your question privately.

The following experiment will last for 6 rounds and you will have to make a decision in each of them. You are randomly assigned to groups of 5 participants which remain fixed over the rounds. At the beginning of the experiment each participant of the group is once endowed with 65 ECU. Your task in each of the 6 rounds is to make a decision on how to use the 65 ECU.

The decision problem

As already described, you are member of a group of five participants in which each member is at the beginning endowed with 65 ECU. In each of the six rounds you have the possibility to contribute any integral number between 0 and a maximum of 10

ECU to a joint account. The amount you have not contributed, you keep (for the time being) for yourself. After each member has made its contribution decision to the joint account, the next round starts, except for the sixth and last round.

The total income of each member of the group after the sixth round is calculated as follows:

Income from the joint account = Sum of all contributions over six rounds x 0.4,

plus the ECU not contributed during the six rounds:

Total Income = Income from the joint account + not contributed ECU.

For example, if after 6 rounds the sum of contributions of all group members to the joint account is 150 ECU, you and any other group member will receive an income of 150 x 0.4 = 60 ECU from the joint account. Additionally, you and all other group members receive the respective ECU that were not contributed to the joint account. If after 6 rounds the sum of contributions of all group members to the joint account is 150 ECU and you have not contributed 35 ECU, you will receive 60 + 35 = 95 ECU.

Thresholds

The total income at the end of round 6 also depends on whether the sum of contributions into the joint account reached certain thresholds after the critical rounds 2, 4 and 6. The threshold for the sum of contributions after the second round is 50 ECU, after the fourth round 100 ECU and after the sixth round 150 ECU. If the sum of contributions after a critical round did not reach the respective threshold, you lose your total income with a probability of 50%.

All necessary random draws are made successively after round 6 (for the rounds 2, 4 and six). It means that you will make a contribution decision into the joint account six times, but will be informed whether you lost your total income if a threshold has not been reached after one of the critical rounds after the end of round 6. The result of the random draws will then be displayed on your computer screen.

The probability of losing everything

If your group contributed less into the joint account than the respective thresholds required after each of the three critical rounds (2, 4 and 6), you lose your total income with a probability of $1/2 + 1/2 * 1/2 + 1/2 * 1/2 * 1/2 = 875/1000 (= 87.5\%)$.

If your group contributed less into the joint account than the respective thresholds required after two of the three critical rounds (rounds 2 and 4, 4 and 6, 2 and 6), you lose your total income with a probability of $1/2 + 1/2 * 1/2 = 75/100 (= 75\%)$.

If your group contributed less into the joint account than the respective threshold required after one of the three critical rounds (round 2, 4 or 6), you lose your total income with a probability of $1/2 (= 50\%)$.

In case your group has reached the respective thresholds after each of the three critical rounds (round 2, 4 and 6), you keep your total income with certainty.

	None of the three thresholds reached	One of the three thresholds reached	Two of the three thresholds reached	All three thresholds reached
Probability of losing the total income	87,5%	75%	50%	0%

If the threshold has been reached after each of the critical rounds, you and your group members earn the income from the joint account (sum of contributions over six rounds x 0.4) plus the ECU that you have not contributed.

If the sum of contributions to the joint account is less than 150 ECU after round 6, even though the thresholds were reached after the other two critical rounds before (i.e. one of the three threshold reached), you and your group members lose the total income with a probability of 1/2 (50%). With a probability of 1/2 (=50%), you are receive the income from the joint account (sum of all contributions over six rounds x 0.4) plus the ECU that you have not contributed. The probability of not losing the whole income is reduced analogously if more than one threshold is not reached. After each round you are told how much each member of the group has contributed to the joint account.

Randomized Events

If thresholds are not reached, it will be randomly decided whether you lose your total income after round 6. One number out of 1 to 1000 is randomly drawn. A number between 1 and 500 translates into a negative result (you lose your total income), while a number between 501 and 1000 translates into a positive result (you don't lose your total income). The number of random draws depends on the number of thresholds that are not reached. We start, if necessary, with the threshold after round 2, followed by, if necessary, the threshold after round 4 and finally, if necessary, the threshold after round 6. After the six rounds, your total income, the results of potential random draws and your earnings (in €) will be shown on the screen. After have finished reading the instructions, please click **Continue**. Afterwards you are asked to answer some comprehension questions.

Please answer the following control questions. The experiment will only start after all participants have answered all questions correctly.

1. Each group member is endowed with 65 ECU. Assume that all five group members (including you) contributed 3 ECU in each of the 6 rounds to the joint account.

   (a) In which critical rounds is the threshold reached (please mark the correct answer)?
   Round 2 ☐ and or
   Round 4 ☐ and or
   Round 6 ☐ or
   None of the three rounds ☐

   (b) With which probability will you lose your total income?

   .....

2. Each group member is endowed with 65 ECU. After the second round, a total 4 ECU have been contributed to the joint account. In the third round, a total of 20 ECU and in the fourth round a total of 26 ECU are contributed to the joint account. After round 6, 165 ECU have been contributed to the joint account.

   (a) After which rounds is the threshold reached (please mark correct answer)?
   Round 2 ☐ and or
   Round 4 ☐ and or
   Round 6 ☐ or
   None of the three rounds ☐

   (b) With which probability will you lose your total income?

   .....

(c) Assume all random draws are to your advantage. Which income do you get from the joint account?

.....

3. Each group member is endowed with 65 ECU. You contribute a constant amount to the joint account in each of the six rounds. The other four group members contribute the same amount to the joint account in each of the six rounds.

   (a) What is the total income you get after round six if you and your group members contribute in every round 10 ECU to the joint account?

   .....

   (b) With which probability are you losing your total income if you and your group members contribute in every round 0 ECU into the joint account?

   .....

4. A total of 155 ECU has been contributed to the joint account. After round six, you have 10 ECU left.

   (a) With which probability are you losing your total income if only the threshold after round six has been reached?

   .....

   (b) With which probability are you losing your total income if only thresholds after round two and six has been reached?

   .....

   (c) What is your total income (in ECU), if all thresholds has been reached?

   .....

Surprise restart (Instructions):
We are repeating this experiment once again. You are once more assigned to a group of five, which will not change for the six rounds. Because of the high number of participants it is very unlikely that you are assigned to the same group of five with the same group members as before.