



To commit or not to commit? An experimental investigation of pre-commitments in bargaining situations with asymmetric information



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ABSTRACT

In a recent paper Konrad and Thum (2014) present a model that shows that unilateral pre-commitment reduces the likelihood of agreement in bilateral negotiations over the provision of a public good when parties have private information over their contribution costs. We test the model in a laboratory experiment paying particular attention to how behavioral motivations other than payoff-maximization affect the strength of the model's result. We find that the result is no longer statistically significant when we allow for non-payoff-maximizing behavior at each stage of the game. Introducing communication has an interesting effect as it influences different forms of non-payoff-maximizing behavior asymmetrically and leads to the model's result again becoming significant. All in all, we find strong experimental support for Konrad and Thum's model even though we observe considerable amounts of non-payoff-maximizing behavior that is not accounted for in the original model.

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1. Introduction

Bargaining over the private provision of public goods may lead to inefficient outcomes if parties have incomplete information or contracts are not enforceable. The literature has largely concentrated on the enforcement problem. Work on international negotiations on environmental regulations, for example, has paid particular attention to the enforcement problem because no common institution exists in this setting and the enforcement of contracts is thus difficult (Carraro and Siniscalco, 1993; Barrett, 1998).

In a recent paper Konrad and Thum (2014) focus instead on the problems that arise in a bargaining environment with asymmetric information. Their model (referred to as KT-model henceforth) assumes the enforcement problem is resolved and examines bargaining over contributions to a public good when parties are privately informed about their cost of provision.

Under asymmetric information bargaining outcomes will generally be inefficient as negotiations can break down with a positive probability even when mutually beneficial agreements are possible (Meyerson and Satterthwaite, 1983). It is well known that in markets for private goods the inefficiency disappears as the number of traders increases and the market becomes large (Gresik and Satterthwaite, 1989). However, Rob

(1989) showed that even this asymptotic efficiency does not hold for public goods and thus under asymmetric information negotiations over the private provision of a public good are unlikely to ever achieve an efficient solution.

The question remains, however, how large the inefficiencies will be and under what kind of negotiation rules the likelihood of negotiation breakdown, and thus the inefficiency, can be minimized. In particular, it is unclear if prior commitments by one party have a positive influence on the prospects for achieving more efficient outcomes. The KT-model makes an important contribution to the literature on the private provision of public goods by investigating this issue in a non-cooperative game setting.

The role of prior commitments is highly relevant. The EU, for example, seems to view pre-committing to environmental damage prevention as an act that sets a good example for others and that will motivate others to follow suit. The KT-model, however, states the exact opposite. Comparing the equilibria of two sequential bargaining games – one with commitment and one without – the authors show that the probability for successful cooperation is strictly lower when one party has contributed to the public good before bargaining takes place. This result obviously has strong political implications.

Our paper is an experimental investigation of the findings of the KT-model. In addition to a direct experimental verification of the model our experiment focuses on the potential for the bargaining situation modeled by Konrad and Thum to be influenced by various motives that deviate from payoff-maximization and which could thus affect the results of the model. Inequality aversion, for example, might prevent players from payoff-maximizing if payoff differences are sufficiently large (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000). Direct and

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indirect reciprocity (Falk and Fischbacher, 2006; Nowak and Siegmund, 2005) may also be a factor in the presence of pre-commitments.

Results from a world-wide survey of people involved in international climate policy indicate that fairness and equity considerations can play a significant role in climate negotiations (Lange et al., 2007, 2010). Since the KT-model's results are particularly relevant for climate negotiations it is thus important to investigate how the model performs in a bargaining environment in which real subjects may harbor such behavioral motivations. A laboratory setting is the ideal venue to explore this extension as the experiment can control for the amount of freedom subjects have to deviate from payoff-maximization.

In order to find out how behavioral motivations other than payoff-maximization affect the results of the KT-model the experiment is designed to be carried out in three settings. Each of the three settings has one treatment with pre-commitment and one without. The first setting is intended to be a direct assessment of the KT-model as it most closely follows the basic assumptions of the original theory, i.e., payoff-maximizing behavior and common knowledge. Technically, one subgame of the KT-model (standard prisoners' dilemma) is replaced by the corresponding Nash payoffs and thus players are forced to behave in a payoff-maximizing way in the final stage of the game. In our experiment we found that in this reference setting cooperation took place twice as often in the treatment without pre-commitment when compared to the treatment with pre-commitment (referred to as cooperation gap henceforth).

In the second setting the entire prisoners' dilemma is introduced to ascertain whether the KT-model is affected by giving subjects additional room to behave in non-payoff-maximizing ways, and if so, whether the cooperation gap persists. We found that the gap did persist in our experiment but became considerably smaller.

In the third setting the KT-model is pushed even further away from its original assumptions through the introduction of pre-play communication between the bargaining parties. There are two motivations for this extension. First, the experimental literature on the provision of public goods has shown that communication between subjects increases the level of cooperation even if communication is cheap talk (Brosig et al., 2003; Valley et al., 1998). It is still unclear, however, what effect communication has in environments with or without pre-commitment. Second, it is an artificial assumption that bargaining over the provision of public goods takes place without communication between the parties involved. It is thus important for the external validity of the KT-model to check whether or not it is communication proof. In fact, in our experiment we observed that with communication there was a strong increase in success rates in both the pre-commitment and no pre-commitment treatments but at the same time the cooperation gap again opened significantly.

The remainder of this paper is structured as follows. The next section outlines the KT-model as it was implemented in our experiment. In section three we specify the experimental procedure. Section four contains our main results, and in the final section five we discuss our findings.

2. The KT-model

The KT-model encompasses two variants of a sequential bargaining game, one with pre-commitment and one without. We start with the more general version without pre-commitment.¹

¹ As the original model is too general to be directly implemented in the laboratory, some basic assumptions of the model had to be slightly adjusted. In particular, the KT-model applies to continuous random variables following arbitrary probability distributions that have a positive inverse hazard rate. In our experiments we use integer variables scaled by factor 10 and a uniform distribution of random variables. Therefore, our presentation of the major results is slightly different compared to the original paper. However, our modification is just a special case of the original theory.

Two players $i \in \{A, B\}$ negotiate over the provision of a public good $e = e_A + e_B$, where e_A and e_B denote the contribution of players A and B respectively. Both players can either make a contribution ($e_i = 10$) or not ($e_i = 0$). If player i decides to contribute, his cost of contribution is $10 + c_i$ with $c_i \in \{1, 2, \dots, 9\}$. The cost parameter c_i is private information of player i and is randomly drawn from a uniform distribution. In the bargaining process, player A can offer a transfer $t \in \{-10, -9, \dots, 9, 10\}$ to player B. If $t > 0$ the transfer goes from A to B which means that A pays a price to B, if $t < 0$ the transfer is a price B pays to A.

The overall bargaining structure is characterized by a take it or leave it offer similar to the classic ultimatum game: Player A proposes a transfer to B which B can accept or reject. If B accepts then both players become obliged to contribute to the public good ($e_i = 10$). If the offer is rejected no transfer is paid and both players decide over their contributions independently. In this case both players are in a prisoners-dilemma and choosing not to contribute is their dominant strategy. Fig. 1 visualizes the sequential structure of the game without pre-commitment.

This version of the model is contrasted with a version in which A makes a commitment before the game starts. Technically, this pre-commitment is modeled by fixing $e_A = 10$ throughout the whole game, which removes strategy $e_A = 0$ from the prisoners' dilemma in the last stage. Thus, player A no longer decides about his contribution and this is common knowledge.

In both cases the payoffs of the players can be written as

$$\pi_A = e_B - c_A \frac{e_A}{10} - t \quad \text{and} \quad \pi_B = e_A - c_B \frac{e_B}{10} + t. \quad (1)$$

Under the assumption of payoff-maximization the KT-model has the following two results.

Result 1 (Konrad and Thum, 2014). *The probability that A and B agree on a cooperative outcome is higher without pre-commitment for all possible c_A .*

Result 2 (Konrad and Thum, 2014). *The unique perfect Bayesian equilibrium transfer is non-positive in the game without pre-commitment and strictly positive in the game with pre-commitment. Specifically, under the conditions implemented in the experiment the equilibrium transfers are given by $t_{hPC}^* = \min\{-\frac{c_A}{2}, -1\}$ in the game without pre-commitment and $t_{PC}^* = 5$ in the game with pre-commitment.*

The intuition behind these results is as follows. If player A does not pre-commit before bargaining takes place then his gain from reaching an agreement is greater. To keep the chances of getting this gain realized A has to bargain less aggressively which enhances the likelihood of cooperation relative to the game with pre-commitment.

Furthermore, if A does not pre-commit then he can sell his willingness to cooperate to B. Player A thus demands a price for cooperation

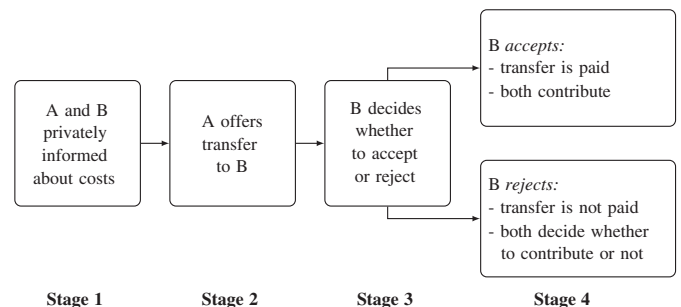


Fig. 1. Sequential structure of the game without pre-commitment.

and we have $t \leq 0$. If A pre-commits, however, he needs to offer B something to make him cooperate and we have $t > 0$.

3. The experiment

3.1. Background

One purpose of the experiment is to detect how behavioral motivations other than payoff maximization affect the strength of the KT-model's predictions. Generally, B -players can deviate from payoff-maximizing behavior in two ways. They may either accept offers although they would be better off rejecting, or reject offers although they would be better off accepting. If observed, these patterns can, however, not be attributed uniquely to a specific behavioral motive. Both for non-payoff-maximizing rejections and acceptances several motives may explain the data.

A non-payoff-maximizing rejection may for example be the result of either negative (direct) reciprocity or inequality aversion. Direct reciprocity refers to a situation in which the first mover A provides a trigger to the second mover B and B directly responds by a choice that affects A 's payoffs.² The case in which offers are rejected although accepting would be the payoff-maximizing choice can be attributed to negative direct reciprocity because it implies that the B -players are directly punishing the offers made by the A -players. Rejections which yield a lower payoff for B -players may also be due to inequality aversion if the B -players deem the payoffs resulting from acceptance to be too unequal.

A non-payoff-maximizing acceptance may be the result of either positive (indirect) reciprocity or a willingness to cooperate. In the treatments with pre-commitments a non-payoff-maximizing acceptance may be driven by upstream reciprocity, which is a form of indirect reciprocity of the type "somebody else helped me and I help you" (Nowak and Roch, 2006). Since the introduction of a fixed pre-commitment puts the B -players in a dominant position it may trigger them to reward the A -players at a cost to themselves even though the pre-commitment was not voluntary.³ In the pre-commitment treatments the acceptance of offers when rejecting would be the payoff-maximizing choice may also be due to a willingness to cooperate as B -players may be more interested in the common good than acting only in their own self-interest.

For A -players, offers that differ from the transfers predicted by the KT-model may also be due to number of behavioral motivations. In the PC game the acceptance of an equilibrium transfer results in an unequal payoff in favor of the B -player so an inequality averse A -player may make lower offers than predicted by theory. In the nPC-game equilibrium transfers result in unequal payoff in favor of the A -player leading an inequality averse A -player to make higher offers than predicted by theory. Offers that differ from the equilibrium transfers may also be due to the A -player taking into account that the B -player may be driven by one of the behavioral motivations such as reciprocity outlined above.

As several motives may explain non-payoff maximizing behavior we keep the discussion of how these motivations explain our results quite general throughout the paper.

The experiment is carried out in three settings that give subjects varying amounts of freedom to follow behavioral motivations other

than payoff-maximization. In all settings we have one treatment with and one without pre-commitment.

- *Setting 1* is the reference setting designed to control for non-payoff-maximizing behavior. If an offer is rejected both players' contributions are fixed to the dominant strategy $e_i = 0$ to force them to play the prisoners' dilemma's Nash equilibrium. The two treatments in this setting are labeled PC_nD_nC (pre-commitment, no decision, no communication) and nPC_nD_nC (no pre-commitment, no decision, no communication).
- *Setting 2* gives both players more room for non-payoff-maximizing behavior because after a rejected transfer they are free to choose whether to contribute to the public good or not. We conjecture that having a choice in the final stage of the game may have a feedback effect on the previous stages. If subjects are completely selfish we should observe no such feedback and we should thus observe no difference between Settings 1 and 2. The two treatments in Setting 2 are labeled PC_D_nC (pre-commitment, decision, no communication) and nPC_D_nC (no pre-commitment, decision, no communication).
- *Setting 3* is the same as Setting 2 but includes a three minute pre-play chat using a chat-box integrated into the user interface. The opportunity for communication occurs in stage one of the game after the subjects learn their cost of provision. Written content is essentially unrestricted but any information that reveals a player's identity is prohibited. The conjecture is that subjects will behave more cooperatively in the communication treatments as has been observed in various experiments on public good provision (Brosig et al., 2003; Valley et al., 1998). The two treatments in this setting are labeled PC_D_C (pre-commitment, decision, communication) and nPC_D_C (no pre-commitment, decision, communication).

Table 1 gives an overview of the three pairs of treatments played in the three settings.

3.2. Experimental setup

Each of our three settings contains two treatments, one without pre-commitment and one with pre-commitment. In each of the six treatments we played six sessions with a different group of ten subjects respectively. Because each subject participated in exactly one specific session, subjects were also different across treatments (between-subject design). At the beginning of a session subjects were randomly selected into the fixed roles of either an A - or a B -player. Over the five rounds the game was played, we used a rotating matching scheme under complete anonymity, i.e. each of the five A -players was paired exactly once with each of the five B -players ("round robin"). As every single subject was well informed about this setup we assume that a player's current decision was made independently from another player's history of decisions. However, among a total of 150 observations per treatment (5 pairs \times 5 rounds \times 6 sessions) we considered subject specific observations dependent which results in 30

Table 1
Overview of all treatments played.

Setting	Name	Pre-play commitment	Post-rejection choice	Pre-play communication
1	nPC_nD_nC	No	No	No
	PC_nD_nC	Yes	No	No
2	nPC_D_nC	No	Yes	No
	PC_D_nC	Yes	Yes	No
3	nPC_D_C	No	Yes	Yes
	PC_D_C	Yes	Yes	Yes

² Even for direct reciprocity alone there exist several different modeling approaches. Intention based reciprocity models focus on what one player believes about the intention of the other player (Rabin, 1993; Falk and Fischbacher, 2006). In type based models people weigh monetary payoffs according to the perceived type of person they face (Levine, 1998). Emotion based models explain reciprocal behavior in terms of relative payoffs and the player's current emotional state (Cox et al., 2007).

³ Note that upstream reciprocity originated from Evolutionary Game Theory which analyzes the evolution of populations given many repetitions of the game. The behavioral pattern we observe here is closest to the character of upstream reciprocity, even though our games were played one-shot.

independent observations per treatment (5 pairs \times 6 sessions).⁴ In total 360 subjects participated in the experiment.

After the roles had been fixed the subjects were given written instructions and sufficient time to read them.⁵ Subjects were informed that their possible cost values ranged from 1 to 9 and were randomly selected with the same probability. Once drawn, we used the same cost values in all sessions to make sessions comparable. The experiment started with three practice rounds in which the subjects played against the computer. All participants were informed that the computer played payoff-maximizing strategies throughout the practice rounds and that these rounds were not payoff relevant. In the first two practice rounds subjects learned the computer's cost as well as their own. The third round simulated the actual game as each player was informed only about their own cost of provision.

At the start of the actual game the subjects were given an initial endowment to ensure that it was not possible for them to make a loss. Subjects were informed that they received an endowment that covered losses but not how high the endowment actually was.⁶ Subjects were not paid a show up fee on top of this endowment. During the game subjects had access to on-screen tables that provided information about relevant payoffs.⁷ These tables included their own payoffs conditional on their and the other players possible decisions, as well as the payoffs of the other player conditioned on the other player's possible costs. The purpose of this information was to make the game easier to follow and to minimize calculation effort.

The experiment was carried out at the experimental laboratory at the University of Magdeburg, Germany (MaXLab) and was programmed using z-Tree (Fischbacher, 2007). The sessions lasted on average 40 min. At the end of the experiment the payoffs of all five games were paid and the average earnings of the subjects were 10.35 euro.

4. Results

4.1. Model predictions versus experimental results

In this section we address the question of whether the theoretical predictions in Results 1 and 2 are compatible with the experimental data of our reference setting (Setting 1), and if so, whether these results still hold given a post-rejection decision (Setting 2) and communication (Setting 3). Table 2 summarizes the (aggregated) experimental data of each treatment. Player A's behavior is captured by the average transfer \bar{t} and the average deviation Δt^* from the predicted equilibrium value. The basic behavior of player B is described by a , the total number of acceptances and r , the total number of rejections. Dividing a by the total number of decisions (150 in each treatment) gives the total acceptance rate that is plotted in Fig. 2 over all three settings.

Result 1 predicts a higher probability of successful negotiation if there is no pre-commitment. In the first setting of our experiment we observed that the acceptance rate was 72 % in the nPC-condition and 36 % in the PC-condition (cf. Fig. 2, Setting 1). Clearly, this difference is statistically significant (p -value < 0.001 , χ^2 -test). Allowing subjects to have a post-rejection decision in the prisoners dilemma (Setting 2) led to the cooperation gap becoming much smaller (55 % vs. 47 %) and no longer being statistically significant (p -value = 0.204, χ^2 -test). Result 1 is, nevertheless, confirmed qualitatively. Finally, adding pre-play communication (Setting 3) increased the agreement rates with and without

⁴ Because of the dependence of observations within an individual we calculated robust variance estimates using clustered individuals. Even if we clustered over sessions we would get essentially the same results.

⁵ See example of instruction in Appendix C.

⁶ We adjusted both players final earnings by making their endowments unequal, otherwise A would have earned nearly nothing on average in the PC-treatments. Letting subjects know about unequal endowments before or during the five rounds played would have affected behavior differently in different treatments, therefore we did not inform subjects about these endowment adjustments.

⁷ See screenshots in Appendix D.

pre-commitment. However, the influence of communication was much stronger without pre-commitment such that the cooperation gap once again opened widely (91 % vs. 73 %) and the difference between the rates once again becomes statistically significant (p -value < 0.001 , χ^2 -test).

Result 2 predicts equilibrium transfers $t_{nPC}(c_A) = -0.5c_A$ in the game without pre-commitment and $t_{PC}(c_A) = 5$ in the game with pre-commitment. To compare these predictions with our experiments we fitted the linear model $t = \alpha + \beta c_A$ in all six treatments using ordinary least squares with observations clustered by subject and robust variance estimates.

Table 3 shows that without pre-commitment the experimental data of Settings 1 and 2 are in line with the prediction. $H_0 : \alpha = 0$ could not be rejected at p values larger than 0.4. The slope estimates are both negative and significantly different from zero and $H_0 : \beta = -0.5$ could not be rejected in Setting 2. With communication involved (Setting 3) the level parameter still corresponds to the prediction ($H_0 : \alpha = 0$, $p = 0.6$) but the transfer seems to become completely unaffected by the cost of Player A ($H_0 : \beta = 0$, $p = 0.7$).

In the three PC-treatments we no longer observed any evident relationship between t and c_A . At all cost levels the transfers spread over their maximum range with correlation coefficients between 0.01 and 0.1 and $H_0 : \beta = 0$ could not be rejected in all three settings. Basically, this observation is in line with the model which predicts that transfer is not affected by the cost level. However, the transfer varies a lot, and while positive, it seems to be lower on average than the predicted value of five (cf. Table 2).

All in all, we see strong experimental evidence in support of Results 1 and 2 of the model, even under conditions that may deviate from the original KT-model.

4.2. Behavioral analysis

We now address the question of how the interplay between different behavioral motivations resulted in the support for the KT-model's main predictions. The behavioral analysis focuses on non-payoff-maximizing behavior and requires a number of refinements of the measures a and r . The variables in columns 5 – 7 of Table 2 represent the number of cases for which the transfer-cost constellation made accepting generate a strictly higher payoff than rejecting (a_{hyp}), rejecting generate a strictly higher payoff than accepting (r_{hyp}), and both decisions generate equal payoffs (i_{hyp}). a_{hyp} is split up into a_{pmx} , the number of times B-players indeed accepted a profitable offer and r_{nmpmx} , the number of times B-players rejected even though accepting was the payoff-maximizing choice. The total number of acceptances a is the sum of a_{pmx} , a_{nmpmx} and a_{ind} , where the latter is the number of B-players who accepted when rejecting and accepting provided the same payoff. Equivalent decompositions hold for r_{hyp} and r .

Fig. 3 shows the number of non-payoff-maximizing acceptances a_{nmpmx} (Fig. 3a) and rejections r_{nmpmx} (Fig. 3b) of the B-players in all three settings. Without pre-commitment we did not find any indication of positive reciprocity or cooperative behavior in the B-players' behavior. Acceptances were clearly payoff driven as the white bars in Fig. 3a show no deviations from payoff-maximization in the nPC-treatments. This is quite different when it comes to the rejections. A considerable number of transfers were rejected although accepting would have provided a higher payoff (cf. white bars in Fig. 3b). This indicates the presence of negative reciprocity or inequality aversion among B-players.⁸

With pre-commitment the pattern was completely reversed: B's rejection behavior was in line with payoff-maximization but the

⁸ As the transfer offered by the A-player is essentially an ultimatum offer it is not surprising that B-players were willing to reject offers which would make them better off but were perceived as unfair. This kind of behavior is well known from ultimatum game experiments (Güth et al., 1982).

Table 2

Behavioral results of all treatments. (1) Behavior of A: $\emptyset t$: Average transfer offered (Lab dollars), Δt^* : Average difference between t and the theoretical equilibrium value t^* (Lab Dollars), *median t*: Median values of the transfers. (2) Expected behavior of B (absolute numbers): a^{hyp} : hypothetical acceptance cases (payoff from accepting was strictly higher), r^{hyp} : hypothetical rejection cases ((expected) payoff from rejecting was strictly higher), i^{hyp} : hypothetical indifference cases (accepting and rejecting had same payoffs) (3) Actual behavior of B: a : total acceptances, a_{pmx} : acceptances when accepting was the payoff-maximizing choice, a_{npmx} : acceptances when accepting was not the payoff-maximizing choice, a_{ind} : acceptances when accepting and rejecting generated equal payoffs (indifference). All rejection variables have the equivalent interpretation given that B rejected the offer. Column "Totals" sums up the respective acceptance and rejections such that $\omega = a + r$, respectively.

Treatment	Behavior of players																
	A			B's exp. beh.			B accepted				B rejected				Totals		
	$\emptyset t$	Δt^*	<i>median t</i>	a_{hyp}	r_{hyp}	i_{hyp}	a	a_{pmx}	a_{npmx}	a_{ind}	r	r_{pmx}	r_{npmx}	r_{ind}	ω_{pmx}	ω_{npmx}	ω_{ind}
nPC_nD_nC	-1.69	0.71	-2.00	129	9	12	108	104	0	4	42	9	25	8	113	25	12
PC_nD_nC	0.77	-4.23	2.00	38	102	10	54	35	11	8	96	91	3	2	126	14	10
nPC_D_nC	-1.88	-0.52	-1.00	122	20	8	82	81	1	0	68	19	41	8	100	42	8
PC_D_nC	1.98	-3.02	3.00	49	88	13	70	49	10	11	80	78	0	2	127	10	13
nPC_D_C	0.22	2.62	0.00	147	2	1	137	136	1	0	13	1	11	1	137	12	1
PC_D_C	-2.84	-2.16	-3.00	52	76	22	109	50	39	20	41	37	2	2	87	41	22

acceptance behavior was not. A's disadvantageous position (relative to B's) caused by the pre-commitment seems to have triggered B's willingness to accept offers even though rejecting would have provided a higher payoff.

It is important to note that the non-payoff-maximizing behavior both in regard to acceptances and rejections work against Result 1 of the KT-model. The non-payoff-maximizing acceptances in the PC-treatments increased the amount of agreements in the games with pre-commitment and the non-payoff-maximizing rejections in the nPC-treatments reduced the amount of agreements in the games without pre-commitment. Given the overall characterization of the behavior of the B-players it is surprising that the predictions of the KT-model are nevertheless confirmed by our findings. To see why this is the case, we have to look more closely at the three settings and we have to take the behavior of the A-players into account.

4.2.1. Setting 1: No last stage decision, no communication

In our reference setting we observed the general behavioral pattern outlined above: Without pre-commitment acceptances were payoff maximizing and rejections were not (e.g. negative reciprocity), whereas with pre-commitment rejections were payoff-maximizing and acceptances were not (e.g. positive reciprocity). As negative reciprocity reduces the number acceptances and positive reciprocity increases it, both observed effects work against the Result 1 of the KT-model.

The reason that there were nevertheless significantly less agreements in the PC-treatment than in the nPC-treatment in this setting

can be attributed to the fact the offers made by the A-players were not high enough in the PC-treatment. Only 38 of the 150 (= 25 %) offered transfers in the PC-treatment would have made the B-player better off by acceptance than by rejection, compared to 129 of the 150 (= 86 %) offers for which this would have been the case in the nPC-treatment. This difference is clearly significant (p -value < 0.001, χ^2 -test).

The KT-model predicts a transfer payment in the PC game of $t_{PC}^* = 5$ but the average transfer payments in the PC-treatment was only 0.77. Thus, behavioral motivations such as inequality aversion appear to have had a strong effect on the behavior of the A-players in the PC-treatment and, as result, the agreement rate fell steeply enough that the difference in the number of agreements reached in the PC-treatment and the nPC-treatment was so pronounced.

4.2.2. Setting 2: Last stage decision, no communication

Under the PC-condition the behavior of the B-players did not change much between Setting 1 and Setting 2. Fig. 3 shows that the introduction of a contribution choice in the prisoners' dilemma made non-payoff-maximizing rejections change from $r_{npmx} = 3$ out of $a_{hyp} = 38$ (8 %) to $r_{npmx} = 0$ out of $a_{hyp} = 49$ (0 %) and the non-payoff-maximizing acceptances change from $a_{npmx} = 11$ out of $r_{hyp} = 102$ (11 %) to $a_{npmx} = 10$ out of $r_{hyp} = 88$ (11 %). Both changes are not significant (p -value > 0.15, χ^2 -test). Put differently, we still observed payoff-maximizing rejection behavior and moderate positive reciprocity or cooperative behavior from the B-players. The transfer behavior of the A-players did not change much either, as the a_{hyp} values in Settings 1 and 2 are quite similar.⁹

The key difference between the two settings can be found in the nPC-condition. In Setting 1 the B-players rejected $r_{npmx} = 25$ out of $a_{hyp} = 129$ (= 19 %) advantageous offers made by A and in Setting 2 this rate was 41 out of 122 (= 34 %). Thus, the tendency towards non-payoff-maximizing rejections by the B-players increased significantly (p -value = 0.01, χ^2 -test) when both players were free to choose their contribution in the prisoners' dilemma. This, in turn, made the number of agreements fall and the cooperation gap close.

This raises the question as to why B-players rejected offers even though the resulting payoff in the non-cooperative solution of the prisoners' dilemma was strictly lower than the safe payoff from accepting. In the treatment in Setting 2 without pre-commitment this type of behavior is only reasonable if the B-players expected that the A-players would not play their dominant strategy in the prisoners' dilemma game. If all players expected every other player to choose the non-cooperative strategy in the prisoners' dilemma then there should be no difference in the r_{npmx}/a_{hyp} values between Settings 1 and 2. But as

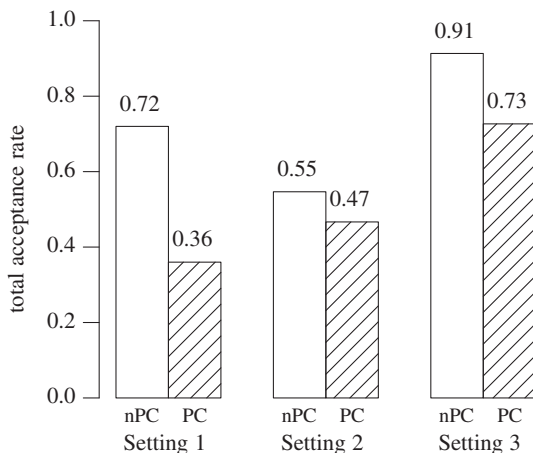


Fig. 2. Variations of the cooperation gap in three experimental settings.

⁹ This behavior is not too surprising as A's decision space is exactly the same in both settings when he has to pre-commit.

Table 3
Parameter estimates and *p*-values of the linear relationship between *t* and *c_A* for all six treatments.

	Coeff.		<i>p</i> -Values (t-test)		
	$\hat{\alpha}$	$\hat{\beta}$	$\alpha = 0$	$\beta = 0$	$\beta = -\frac{1}{2}$
nPC					
nPC_nD_nC	0.002	-0.35	0.996	<0.001	0.025
nPC_D_nC	0.427	-0.48	0.416	<0.001	0.873
nPC_D_C	0.484	-0.06	0.618	0.689	0.003
PC					
PC_nD_nC	2.31	-0.32	0.056	0.028	0.124
PC_D_nC	3.02	-0.22	0.007	0.070	0.274
PC_D_C	2.96	-0.02	0.000	0.007	0.854

we did observe a difference it can be attributed to *B*'s expectation to exploit the other player in the final stage.

4.2.3. Setting 3: Last stage decision, communication

Adding pre-play communication in Setting 3 neither affected non-payoff-maximizing acceptances under the nPC-condition nor did it affect non-payoff-maximizing rejections under the PC-condition.¹⁰ With communication *B*-players still did not reward *A*-players at cost to themselves when *A* was not disadvantaged by pre-commitment, and *B*-players still did not punish *A*-players at cost to themselves when *A* was disadvantaged by pre-commitment. However, the arrows shown in Fig. 3 indicate that communication did (i) increase the non-payoff-maximizing acceptances under PC (*a_{npmx}* increased from 10 out of *r_{hyp}* = 88 (= 11%) to 39 out of *r_{hyp}* = 76 (= 51%)) and (ii) reduced the non-payoff-maximizing rejections under nPC (*r_{npmx}* falls from 41 out of *a_{hyp}* = 122 (= 34%) to 11 out of *a_{hyp}* = 147 (= 7%)). Therefore, communication influences *B* towards cooperation in two different ways: On the one hand it led *B* to share in the disadvantage of *A*'s pre-commitment and accept non-profitable transfers (*a_{npmx}* increases), on the other hand it neutralized the expectations *B* had of exploiting *A* that were present without communication in the nPC-condition (*r_{npmx}* falls). The first effect works against Result 1 of the KT-model, the second one supports it.

If communication had no other effect we should have observed that the cooperation gap remained unchanged. The reason why the cooperation gap opened again in Setting 3 is that communication also affected the generosity of the *A*-players. Average transfers $\emptyset t$ as well as the number of offers *a_{hyp}* that a payoff-maximizing actor would accept take their highest values in Setting 3.¹¹ This made the number of payoff-maximizing acceptances rise by $\Delta a_{pmx} = 55$ and the number of payoff-maximizing rejections change by $\Delta r_{pmx} = -18$ under the nPC-condition. In total this effect is stronger than under the PC-condition ($\Delta a_{pmx} = 1$ and $\Delta r_{pmx} = -41$), supporting Result 1 of the model.

4.3. Estimation of treatment effects

As a final piece of analysis we use our experimental data to estimate the logistic regression model

$$\Pr(Acc_B = 1) = \Lambda(\alpha + \beta_1 t + \beta_2 c_B + \gamma_1 D_1 + \dots + \gamma_5 D_5) \quad (2)$$

in which *Acc_B* (Did Player *B* accept? Yes = 1, No = 0) represents the binary outcome variable and $\Lambda(z)$ is the logistic link function. The

¹⁰ See Appendix B for a detailed discussion of how communication was used by the subjects. It is worth noting here that the opportunity to communication was utilized extensively in both treatments although more often in the treatment without pre-commitment.

¹¹ Note that this effect of communication was so strong that even the $\emptyset t$ in the PC-condition became positive, which is difficult to explain in the context of the KT-model.

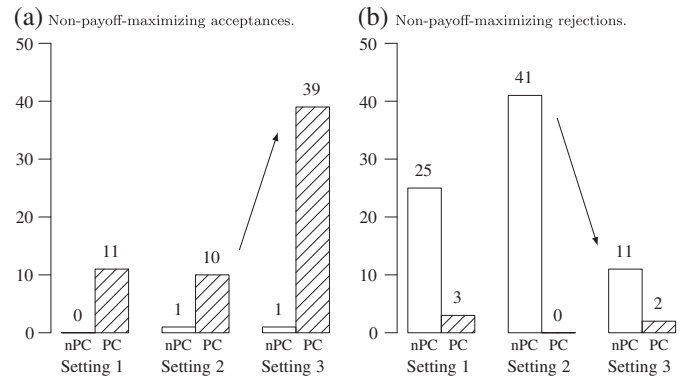


Fig. 3. Deviations from payoff-maximization over all treatments. Values above the bars represent the absolute number of *B*-players. The arrows indicate the effect of communication.

success probability $\Pr(Acc_B = 1)$ is explained by the predictors *t* (transfer offered by Player *A*) and *c_B* (costs of Player *B*) and five treatment dummies *D₁* to *D₅*. The Maximum-Likelihood fit of Eq. (2) and some technical detail on the estimated model's characteristics can be found in Appendix A.

Here, we start by using the fitted model to estimate the Average Marginal Effect (*AME*) of each of the predictors, which quantifies their average isolated effect on success probabilities when controlling for all other variables.¹² The first two rows of Table 4 show that the average effect of *B*'s costs on success probabilities is negative and significant (z-Test, *p*-value < 0.001), whereas for the transfer *t* the *AME* is positive and significant. The remaining seven rows display the isolated effect of a treatment relative to a baseline both within (rows 3 - 5) and across (rows 6 - 9) the three settings. It is important to note that these comparisons differ conceptually from those carried out to quantify the cooperation gaps in Section 4.1. The cooperation gap is defined as the difference in the acceptance rates between two treatments. The acceptance rates themselves are not only influenced by whether there is a pre-commitment or not, but also by the transfers and costs that are present in each of the treatments being compared. Consequently, the evolution of *AME* values over the three settings draws a different picture than the observed cooperation gaps. In our reference setting the *AME* of pre-commitment is very strong (*AME* = -0.51) and becomes successively weaker under a post-rejection decision (*AME* = -0.38) and communication (*AME* = -0.35). In all three settings the isolated effect of a pre-commitment on success probabilities is negative and significantly different from zero.

The last four rows in Table 4 are across setting comparisons. We see that the introduction of the post-rejection decision has a significant negative effect without pre-commitment (*AME* = -0.12), whereas under pre-commitment this effect disappears (*AME* = 0.02, *p*-value = 0.6, z-Test). Finally, introducing communication has a positive and statistically significant effect without pre-commitment (*AME* = 0.18) and with a pre-commitment (*AME* = 0.20).

Clearly, the averages of the marginal effects are useful, but the aggregation of multidimensional data into a single number always eliminates information. For example, *AME*s hardly allow for drawing conclusions about non-payoff-maximizing behavior or to identify those combinations of transfer *t* and cost *c_B* for which a treatment effect is the strongest. For that reason we also plotted the individual marginal treatment effects at every hypothetical combination of transfer *t* and cost *c_B*. Fig. 4 visualizes this approach for each of the four across setting comparisons.

¹² See (Long and Freese, 2006) for details on the calculation of marginal effects of continuous and categorical predictors.

Table 4
Average marginal effects of continuous variables, within setting comparisons and between setting comparisons.

		AME	Robust \widehat{sd}	z	P > z	95 % conf. int.	
						Lower	Upper
c_B		-0.07	0.004	-15.73	<0.001	-0.08	-0.06
t		0.07	0.005	12.47	<0.001	0.06	0.08

Baseline	vs.	AME	Robust \widehat{sd}	z	P > z	Lower	Upper
nPC_nD_nC	PC_nD_nC	-0.51	0.049	-10.41	<0.001	-0.61	-0.42
nPC_D_nC	PC_D_nC	-0.38	0.037	-10.26	<0.001	-0.45	-0.30
nPC_D_C	PC_D_C	-0.35	0.052	-6.85	<0.001	-0.45	-0.25
nPC_nD_nC	nPC_D_nC	-0.12	0.038	-3.04	0.002	-0.19	-0.04
PC_nD_nC	PC_D_nC	0.02	0.041	0.52	0.6	-0.06	0.10
nPC_D_nC	nPC_D_C	0.18	0.042	4.25	<0.001	0.10	0.26
PC_D_nC	PC_D_C	0.20	0.044	4.56	<0.001	0.12	0.29

Fig. 4a and b display the effect of a post-rejection decision with and without pre-commitment. Without pre-commitment we see a negative effect so introducing a post-rejection decision must have led some B-players to reject when they would have accepted otherwise. The solid black line represents all transfer/cost constellations for which B should be theoretically indifferent between accepting and rejecting. Above that line accepting results in higher payoffs, below it rejecting is more profitable. As the darkest shading (i.e. the strongest effect) is located strictly above that line a considerable number of B-player must have rejected even though it was not payoff-maximizing. This is in line with our previous conjecture that B-players began to develop expectations about exploiting the A-players in the prisoners' dilemma or simply wanted to punish A at cost to themselves.

In contrast to that, Fig. 4b shows that, when A had to pre-commit, the effect of a post-rejection decision was miniscule but positive and is located strictly below the indifference line.¹³ Put differently, if there was an effect at all under pre-commitment, then it was one of positive reciprocity or willingness to cooperate, i.e. accepting non-payoff-maximizing offers.

Performing the same analysis for the effect of communication we observe a positive treatment effect from communication both without pre-commitment (Fig. 4c) and with pre-commitment (Fig. 4d). Communication must thus have made B players accept who would have rejected otherwise. Without pre-commitment those B-players who would have rejected without communication are those that should have accepted if they were payoff-maximizing because the darkest shading is located strictly above the indifference line. In other words, communication led to an increase in acceptance probabilities because it reduces non-payoff-maximizing rejections when no pre-commitment is involved. With pre-commitment those B-players who would have rejected without communication are those that should have rejected if they were payoff-maximizing because the darkest shading is located strictly below the indifference line. As communication made these players accept anyway, the increase in acceptance probabilities can be attributed to an increase in positive reciprocity or willingness to cooperate when pre-commitment is involved.

5. Discussion

Our experimental results lend considerable support to the main predictions of the KT-model, even though subjects in our experiment were influenced by behavioral motives that are not taken into account in the original model. The experiment revealed behavior consistent with a tendency towards cooperation, positive and negative reciprocity, and

inequality aversion. All these traits can work against Result 1 of the model. Cooperative behavior and positive reciprocity can lead to more agreements under pre-commitment and negative reciprocity to less agreement without pre-commitment. So if subjects had been led more by reciprocity or social preferences than by payoff-maximizing behavior the theoretical results could well have failed to hold. Nevertheless, in all our comparisons we observed that a pre-commitment reduced the likelihood of an agreement being reached.

Communication between the players also had an interesting effect. As we have come to expect from past experiments communication led to subjects having a higher willingness to deviate from payoff-maximization and behave cooperatively. Given this, we expected the treatment with communication to strengthen the effects such as cooperative behavior and reciprocity that can work against the model's results. However, while communication did have the expected effect on the willingness to cooperate it also led to a sharp fall in negative reciprocity and on the attempts of the B-players to exploit the A-players in the treatment without pre-commitment. Combined this resulted in the number of agreement being reached being the highest of all treatments in the no pre-commitment treatment with communication. This in turn led to the difference between pre-commitment and no pre-commitment increasing with communication and the difference once again being statistically significant.

All in all, our experimental results provide important backing to the main conclusion of the KT-model regarding the potentially counterproductive effects of pre-commitments in climate negotiations. We have shown that even if negotiating parties are driven by behavioral motives outside the model the results of the model can still be expected hold. Moreover, we have shown that if the environment is extended to include the realistic feature of communication between parties the main conclusion still holds strong.

A possible critique of the KT-model – and thus our experimental investigation – is that the pre-commitment of the A-players is not voluntary. It could be argued that in the case of voluntary pre-commitments positive reciprocity would be more pronounced. There are good reasons for not testing this by running experiments with voluntary pre-commitments using the KT-model. First, given the specific bargaining situation, we cannot expect to observe any voluntary pre-commitment. If A-players have the choice between committing and not committing, they will certainly opt for not committing, even if they harbor some kind of other regarding preferences. The reason is that to pre-commit actually increases the inequality of final payoffs.

Therefore, an inequality averse player would also choose to not pre-commit and would offer a low price ($t = 0$) which ensures that the B-player will agree to cooperate and which leads to equal payoffs for both players. Consequently, there is no motivation discussed in the literature on other regarding preferences which would make pre-commitment a rational choice.

This goes in line with the fact that we rarely observe truly altruistic pre-commitments in reality. In the context of climate damage abatement, for example, the pre-commitment is usually sold as having the advantage of allowing countries that pre-commit to gain a competitive advantage in the development of cleaner technologies and not out of some altruistic consideration.

Furthermore, previous experiments on the effect of pre-commitments in which these were voluntary have shown little evidence for reciprocity which go beyond that which we observed in our experiment. In the literature on leadership in climate negotiations we have seen only moderate levels of reciprocal behavior towards pre-commitments (Werner Güth et al., 2007; Vittoria Levati et al., 2007; Gächter et al., 2012; Sturm and Weimann, 2008). In a sequential bargaining experiment Brosig et al. (2004) find that voluntary pre-commitments are greatly taken advantage of and in a current paper Heinrich and Weimann (2014) find that in dictator games in which recipients could choose

¹³ Note that the shading is so bright that it may become invisible in some printouts. We kept this color coding anyway to maintain comparability to the other three figures.

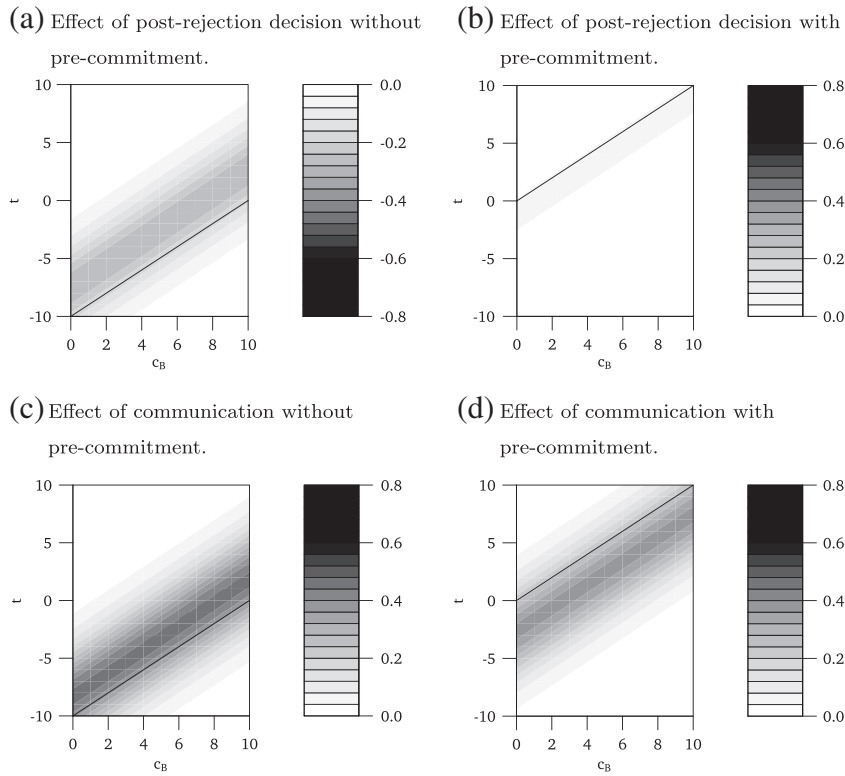


Fig. 4. Treatment effects on estimated acceptance probabilities over all transfers t and costs c_B . Darker shadings represent stronger effects on the estimated acceptance probability. The black line represents theoretical t/c_B -combinations for which a payoff-maximizing B should be indifferent between accepting and rejecting.

between different modified dictator games there was no reciprocity shown by dictators. Thus, there is no current experimental evidence that suggests a voluntary pre-commitment would lead to more reciprocity than that which we observed in our experiment.

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Appendix A. Logistic regression results

Table A.5

Logistic regression with nPC_nD_nC as baseline. Because of the dependence of observations within a subject we calculated robust variance estimates using the cluster() option in STATA. Model characteristics: (1) No multicollinearity: All variance inflation factors are $\ll 10$, (2) No perfect separation (3) Likelihood-Ratio test for overall fit: $\chi^2 = 153.04$, $p < 0.001$ (4) Predictive accuracy: In 84.5 % of all cases the observed 1 (0) was predicted at $p > = 0.5$ ($p < 0.5$).

	$\hat{\beta}$	Robust \hat{sd}	z	p	Odds ratio	95 % conf. int.	
						Lower	Upper
(Intercept)	4.81	0.538	8.95	<0.001	-	-	-
Transfer t	0.56	0.064	8.74	<0.001	1.76	0.44	0.69
Cost c_B	-0.57	0.057	-10.00	<0.001	0.57	-0.68	-0.46
PC_nD_nC	-4.26	0.670	-6.35	<0.001	0.01	-5.57	-2.94
nPC_D_nC	-1.13	0.401	-2.82	0.005	0.32	-1.92	-0.35
PC_D_nC	-4.07	0.538	-7.56	<0.001	0.02	-5.13	-3.02
nPC_D_C	0.84	0.571	1.47	0.141	2.32	-0.28	1.96
PC_D_C	-2.49	0.547	-4.56	<0.001	0.08	-3.56	-1.42

Appendix B. Analysis of communication

A closer look at how the communication was used in the two treatments can shed some light on the widening of the cooperation gap. Table B.6 shows how the chats were used in the two treatments with communication. As can be seen cost information was revealed in more cases in the nPC_D_C-treatment (71 %) than in the PC_D_C-treatment (42 %) with the share of truthful revelation being roughly the same between the two (60 % vs. 69%). After there was a communication about costs there was a strong tendency to reach an agreement. Furthermore, the tendency was stronger in the nPC_D_C-treatment than in the PC_D_C-treatment (94 % vs. 72 %). Thus, the fact that both costs were revealed more often and that the tendency to reach agreement after a cost revelation was stronger in the nPC_D_C-treatment is consistent with the widening of the cooperation gap.

In the nPC_D_C-treatment 65 % of the subjects made a firm commitment to come to an agreement in the chat while in the nPC_D_C-treatment it was 53 %. Again, there was a strong tendency of offers to be accepted after a clear agreement was reached in the chat (97 % and 90 %). This difference between agreements reached in the chats is again consistent with a widening of the cooperation gap.

Table B.6

Communication in Setting 3.

Cases in which...	nPC	PC
... A and B revealed own cost in chat	214 (71.3%)	127 (42.3%)
... revealed cost was true value	129 (60.3%)	87 (68.5%)
... A and B agreed after costs were revealed	202 (94.3%)	91 (71.7%)
... A and B agreed in chat	194 (64.7%)	160 (53.3%)
... A and B agreed in game	189 (97.4 %)	144 (90.0 %)

Appendix C. Instructions

The following text represents the instructions in the nPC_D_nC-treatment (translated from German):



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i Rules and instructions, please read carefully!

1. **Before the experiment** switch-off your mobile phone. Read carefully the instructions below and inform the experimenter by a show of hands if you have questions.
2. **During the experiment** you are neither allowed to talk nor to leave your place. We let you know when the experiment is finished. If your screen does not respond to your entry immediately, another player has not decided yet. Please be patient.
3. **After the experiment** you get your payoff. Please remain seated until you are called.

General procedure: Before the actual experiments you will play 3 practice rounds against the computer. These practice rounds are not payoff relevant. The purpose of these rounds is to familiarize yourself with the experimental environment. The computers behavior will not be arbitrary but fully payoff-maximizing. In order that you are fully able to comprehend the computers actions you will be given the computers private cost information in the first two practice rounds. This information will be unknown to you both in the third practice round as well as in the actual game.

In the following 5 rounds you will play the actual experiment in which you will play each other participant once. At the start you will receive an endowment which can grow or shrink depending on your actions in each of the rounds. Your final payoff after the 5 rounds will certainly be positive. There are a total of 10 participants, 5 of which will be given the role of an A player and 5 the role of a B player. In each round the first decision will always be made by A and the second by B. The B player will thus be able to observe the action taken by the A player before making a decision. Designated roles will stay the same throughout the experiment.

Content of the experiment: In each of the rounds you and the other player can contribute some effort e towards the provision of a common good. The size of e is measured in lab dollars with 5 lab dollars being worth 1 euro. The choice $e = 10$ means that you will contribute the effort, and $e = 0$ means you will not contribute the effort. Other values of e are not possible. You and the other player will receive the sum of both your contributions. That is, 0 (if neither of you contributed), 10 (if one of you contributed), 20 (if you both contributed). This payoff will be reduced by your cost of contributing. The cost will be zero if you do not contribute ($e = 0$) and $10 + c$ if you do contribute ($e = 10$). The whole number c is randomly selected and lies between 1 and 9, with each of the nine values being equally probable. Before each round each player will find out their own cost but not the cost of the other participant.

The A player can offer the B player a transfer payment which can take any whole number between -10 and $+10$. Positive values mean there is a payment from A to B and negative values mean there is a payment from B to A. Player B can either accept or reject the transfer offer. If the B player accepts the transfer payment will be made and both players are required to contribute the effort $e = 10$ (you will then no longer be able to decide over this freely as $e = 10$ will be set automatically). If B rejects the offer then both players can choose freely whether to contribute or not, i.e., you can either choose $e = 10$ or $e = 0$.

Experimental timeline:

- **Stage 1:** Player A receives the cost information $10 + c_A$ and offers B a transfer $-10 \leq t \leq 10$
- **Stage 2:** Player B receives the cost information $10 + c_B$ and decides whether to accept the offer or not.
- **Acceptance, Stage 3a:** $e = 10$ is set for both players.
- **Rejection, Stage 3b:** Both player decide between $e = 10$ and $e = 0$, without knowing the decision of the other player.

After Stage 3 the current round ends and you are informed about your current payoff. Payoffs from previous rounds are logged and made available to you in each round.

Payoffs: Lab-dollars π in a round are determined as follows (red for Player A, blue for Player B):

- If B accepts (Stage 3a):

	gross payoff	−	costs	±	transfer
$\pi_A =$	20	−	$(10 + c_A)$	−	t
$\pi_B =$	20	−	$(10 + c_B)$	+	t

- If B rejects (Stage 3b):

effort		B			
		$e_B = 0$		$e_B = 10$	
A	$e_A = 0$	0	0	10	$-c_B$
	$e_A = 10$	$-c_A$	10	$10 - c_A$	$10 - c_B$

Appendix D. Screenshots

Your cost:
15

Your income at different transfer amounts

Transfer:	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
Your income:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5

Player B's income at different transfer amounts

Transfer:	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
B's Income:	-Cb	1-Cb	2-Cb	3-Cb	4-Cb	5-Cb	6-Cb	7-Cb	8-Cb	9-Cb	10-Cb	11-Cb	12-Cb	13-Cb	14-Cb	15-Cb	16-Cb	17-Cb	18-Cb	19-Cb	20-Cb

Possible income if offer is rejected

	You both choose 0	You choose 10 and player B 0	Player B chooses 10 and you 0	You both choose 10
Your income	0	-5	10	5
B's income	0	10	-Cb	10 - Cb

How much do you wish to offer?

Fig. D.5. Screen of player A in Setting 2 and nPC.

Your cost:
17

Player A's offer:
4

Your income if you accept
7

Player A's income at different cost if you accept the offer

A's possible costs:	1	2	3	4	5	6	7	8	9
A's income:	5	4	3	2	1	0	-1	-2	-3

Possible income if offer is rejected

	You both choose 0	You choose 10 and player A 0	Player A chooses 10 and you 0	You both choose 10
Your income	0	-7	10	3
A's income	0	10	-Ca	10 - Ca

Do you accept the offer?

Accept the offer
 Reject the offer

Fig. D.6. Screen of player B in Setting 2 and nPC.

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