See No Evil: Information Chains and Reciprocity*

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Abstract

We study experimentally voluntary contributions to public goods when none, some, or all previous decisions are observable. When agents observe previous moves, they tend to condition their cooperation on observed cooperation. This leads to two effects of increased transparency: on the one hand, early movers are more likely to cooperate in order to encourage those who observe them to cooperate. On the other hand, as transparency increases, later movers are less likely to cooperate because they are more likely to observe defections and defect in response. With increasing returns to scale, where the effect of one agent's contribution is larger as more agents contribute, an information chain is as effective in inducing cooperation as full transparency. In a linear public good, where agents lose in monetary terms by contributing to the public good, information chains induce higher cooperation in early movers compared to a no-transparency treatment and in late movers compared to a full-transparency treatment. Thus, partial information can be used to balance the positive and negative effects of transparency.

Keywords: public goods, team production, incentives, externality, information, transparency, conditional cooperation.

JEL: C72, C92, D21, H41, J31, M52

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1 Introduction

The nature of some public goods is such that agents decide on their (voluntary) contributions sequentially. This is the case in some common resource pool situations such as large-scale, centrally constructed irrigation systems, where those who are located closer to the source of the water have first opportunity to withdraw water from the system (Ostrom and Gardner, 1993) or inshore fisheries with seasonal migrations (Schlager et al., 1994). Moreover, some public goods, such as public infrastructure or scientific research, are typically produced by a sequential process involving several agents (e.g., architect, supplier, and constructor or theoretician, lab technician, and statistician, etc.) Fundraising activities as well are often performed sequentially, both in small groups such as churches (Soetevent, 2005) and in large groups such as in nationwide telethons.

In such cases, agents may have varying degrees of information about previous contributions. This information has the potential to influence contribution decisions in different ways.[1] On the one hand, early movers are more likely to cooperate in order to encourage those who observe them to cooperate. On the other hand, later movers are less likely to cooperate as transparency increases because they are more likely to observe defections and defect in response.[2] In many cases, a central designer can influence the flow of information between contributing agents. This may happen in interdisciplinary research, where collaborators often do not have the expertise or information needed to assess the quality of others' contributions. The head of a medical study, for example, can provide the clinician with information about the quality of the sample construction. Similarly, the head of a fundraising project can choose what information about previous donations to make public (List and Lucking-Reiley, 2002; Silverman et al., 1984; Soetevent, 2005). The design of environments aimed at facilitating contributions should thus consider the optimal level of transparency while taking into account both its positive and negative effects on cooperation levels.

In this paper, we experimentally study these issues by comparing cooperation under different levels of transparency. Several experimental studies have explored situations in which some players have information about the contributions of other players at the time of making a contribution. However, in all the studies of which we are aware, informed players have perfect information about all previous moves.[3] In contrast, the aim of our

[1]In some cases, agents do not observe previous moves, but can condition their contribution on the contribution of others as in, for example, committing to match funds the that will be provided by another agent (see, e.g., Guttman, 1978, for an analysis of matching mechanisms with simultaneous moves).

[2]The opposite may apply when contributions of different agents are substitutes, for example in sequential chicken games. This is not the case in the environments we study in this paper.

[3]Theoretical studies include Hermalin (1998); Romano and Yildirim (2001); Varian (1994); Vesterlund (2003). Experimental studies include Andreoni et al. (2002); Chen and Komorita (1996); Coats and Neilson (2005); Dorsey (1992); Figuieres et al. (2012); Gächter et al. (2010); Kurzban and Houser (2005); Kurzban et al. (2001); Levati et al. (2007); Levati and Zultan (2011).

experimental investigation is to test the efficacy of partial and imperfect transparency. The theoretical analyses we present in the paper suggest that the effects associated with full transparency are expected to occur as long as there is (direct or indirect) information flow between any two agents in the group. Accordingly, we focus on *information chains*, in which each agent only observes the decision of the preceding mover. Information chains present the minimal information structure that satisfies the theoretically-derived requirement. As such, they provide the best experimental tool allowing to capture general insights into the performance of partial transparency, as it naturally occurs, for example, in inshore fisheries with limited communication over large distances along the shore.

We study the effects of transparency under two different technologies. The first exhibits increasing returns to scale, i.e., the marginal effect of an agent's contribution is strictly increasing in the number of other agents who choose to contribute. The second technology defines a standard linear public good, in which the marginal amount of public good provided by each agent's contribution is fixed. We develop a theoretical model, following that of Winter (2010), to show that partial transparency is predicted to perform as well as full transparency in inducing cooperation under increasing returns to scale. We proceed to argue that if agents are intrinsically conditional cooperators due to reciprocal preferences, similar effects might be expected even in the linear public good. Furthermore, as early movers should be more likely to contribute because they are observed by more potential followers whereas late movers should be less likely to contribute because they observe more potential defectors, we predict that the positive effects of transparency decrease along the chain of agents.

Our experimental results validate the theoretical predictions under increasing returns to scale, with partial transparency resulting in high cooperation similar to that observed with full transparency. The effects of transparency are not evident in early periods, but become apparent over time as group members who play according to the equilibrium prediction prompt their partners to follow suit.

Significant conditional cooperation is also observed in the linear public good, where cooperation is not consistent with an equilibrium based on monetary payoffs alone. Participants are consistently and significantly more likely to contribute if every other participant they observe has contributed. However, the magnitude of conditional cooperation is considerably lower than with increasing returns to scale, so that overall contribution levels do not differ significantly depending on the transparency level. Nonetheless, we find that both full and partial transparency have a significantly positive effect on early movers, whereas full transparency has a significantly negative effect on late movers. As a result, highest contribution levels are observed in the information chain, since it benefits from the positive effect of reciprocity on early movers, while avoiding the detrimental effect on late movers.

The rest of the paper is organised as follows. We present the theoretical arguments and the resulting hypotheses for technologies with increasing returns to scale and linearity in Sections 2 and 3, respectively. In Section 4 we develop a formal model underpinning the hypotheses drawn in the preceding sections. Sections 5 and 6 describe the experimental design and results and Section 7 concludes.

2 Transparency with increasing returns to scale

The interaction between transparency and technology was theoretically studied in a principal-agent model by Winter (2006, 2010), who characterized the optimal reward mechanisms that can induce effort in teams under different information structures and different production technologies. An optimal mechanism determines the reward that each agent receives contingent on the team outcome such that all agents exert effort in equilibrium. Winter (2006) showed that when the production function has increasing returns to scale, transparency increases efficiency in equilibrium. Due to the complementarities in the technology, an observed contribution by one agent can incentivize the observing agents to contribute as well, thereby increasing the incentives of the observed agent.[4]

However, this clear intuition is not enough to determine the efficacy of different partial-transparency environments. Winter (2010) addressed this issue by extending the framework to compare different information structures. Winter proved that one information structure is more transparent (and therefore efficient) than another if the *closure* of the directed graph representing the latter is included in the closure of the directed graph representing the former, i.e., if every arc that exists in one also exists in the other (Winter, 2010, Proposition 4, p. 13). In other words, if agent i observes agent j, and agent j observes agent k, whether i observes k directly or not does not affect the optimal mechanism required to extract full contributions from the agents. This result is driven by the fact that the effect of the transparency is maximized when each agent benefits from contributing if and only if she does not observe any defections. In this case, when i observes j contributing, she infers that k has also contributed, otherwise contribution would have been dominated for j.

It follows that the minimal information structure required to maximize the incentivizing effect of transparency is an *information chain*, such that the agents decide sequentially and each agent observes only the action of her immediate predecessor. That is, *indirect* transparency can be as efficient as *direct* transparency in facilitating cooper-

[4]This may lead to paradoxical incentive reversals, as increasing the incentives of the observing agent may remove the incentives of the observed agent. (See Klor et al., forthcoming; Winter, 2009)

ation in teams. This premise is the starting point of our experimental investigation into sequential contributions to public goods. We compare contribution decisions in three different information treatments:

No information (NI):	Agents do not observe the contribution decisions of other agents.
Chain information (CI):	Each agent observes only the contribution decision of her immediate predecessor.
Full information (FI):	Each agent observes the contribution decisions of all previous movers.

Treatments NI and FI are equivalent to the simultaneous and sequential protocols previously studied in the literature, respectively. We construct the environment such that, with increasing returns to scale, all agents contribute in the unique subgame-prefect equilibrium outcome of FI, whereas zero contributions consist a Nash equilibrium in NI. This environment provides the backdrop against which we study indirect transparency, as manifested in our CI treatment. Our first hypothesis addresses the basic effect of transparency while the second reflects the prediction with regard to partial transparency:

Hypothesis 1. *Contribution levels in FI are higher than those in NI.*

Hypothesis 2. *Contribution levels in CI are as high as those in FI.*

3 Transparency in a linear public good

Hypotheses 1 and 2 crucially depend on the agents playing reciprocal strategies, such that an agent contributes if and only if everyone she observes has contributed.[5] These strategies can be in equilibrium due to the production technology involving complementarities between the contributions of the agents. Nonetheless, it is possible that transparency may lead to cooperation even without the complementarities induced by the explicit technology, based on intrinsic reciprocal preferences. The experimental literature provides abundant evidence that people have a preference to cooperate at a personal cost only if others cooperate as well. For example, 32.9% of the participants in the study of Fischbacher and Gächter (2010) responded to full contributions of the other group members by contributing their full endowment.[6]

[5] We distinguish between *reciprocal preferences* and *reciprocal strategies*. The latter do not necessarily reflect the former, as in our equilibrium analysis under increasing returns to scale.

[6] See also Ashley et al. (2010); Brandts and Schram (2001); Fischbacher et al. (2001); Guttman (1986); Keser and Van Winden (2000); Kurzban and Houser (2005); Levati and Neugebauer (2004); Levati and Zultan (2011). Gächter (2007) provides a recent review.

If a sufficiently large number of agents are conditional cooperators, a contribution made by an observed agent is likely to lead to contributions by subsequent movers. Thus, the effects of transparency predicted under a technology with increasing returns to scale are also likely to exist under a linear technology, in which there are no complementarities in material payoffs, so that all selfish money-maximizing agents have a dominant strategy to defect. Some support for this conjecture is provided by several field experiments showing that charitable contributions are increased if information about previous contributions is provided (Croson and Shang, 2008; Frey and Meier, 2004; List and Lucking-Reiley, 2002; Shang and Croson, 2009; Silverman et al., 1984; Soetevent, 2005).

However, the coin of conditional cooperation has two sides. Thus far we have considered positive reciprocity, i.e., the tendency to be kind to those who are kind, either due to the explicit incentives structure or to an intrinsic propensity for conditional cooperation. The analysis of equilibria under increasing returns to scale reveals how increased transparency utilizes positive reciprocity, inducing observed agents to contribute in order to motivate their followers to contribute as well. Nonetheless, Incorporating an intrinsic preference for reciprocity suggests an additional opposite effect of negative reciprocity, namely, late movers who would have contributed in the absence of information about their predecessors' decisions may withhold contributions once observing defection. Accordingly, we hypothesize that both positive and negative reciprocity play a role in contribution decisions and have an increasing effect as transparency increases. Furthermore, the effect of positive reciprocity diminishes along the chain of agents, as later movers are observed by fewer agents and therefore have a decreasing incentive to motivate future movers. Conversely, the effect of negative reciprocity is enhanced along the chain of agents, as later movers have a higher probability of observing defection. Our third hypothesis reflects this effect:

Hypothesis 3. *The propensity to contribute is affected by an interaction of the transparency level and the position in the chain of agents. Agents who move early in the chain are more likely to contribute as transparency increases from NI to CI and FI, whereas this effect is reversed for agents who move late in the chain.*

4 Model

Each of a set N of n agents makes a binary decision whether to contribute to a public good. Each agent i decides whether to contribute ($s_i = 1$) or to defect from contributing ($s_i = 0$). Contributing agents pay a personal cost C, which is fixed and equal for all agents. The amount of public good provided is given by a technology $p(k) \in \mathbb{R}$, where $k = \sum_{j \in N} s_j$ is the number of contributing agents, and p is increasing in k. The benefit that agent i receives from the public good depends on a commonly-known individual benefit factor b_i. The overall payoff for i is therefore:

$$\pi_i = p(k)b_i - s_i C$$

The set of agents that an agent i observes is denoted K_i. Therefore, the information available to agent i is $I_i = \{s_j, j \in K_i\}$. The strategy of agent i is a function $s_i : 2^{|K_i|} \to \{0, 1\}$, indicating whether i contributes or defects as a function of the information she observes, i.e., the contribution decisions of all agents in K_i. The three information structures given above can now be defined thus:

NI: $K_i = \emptyset$ for all $i \in N$

CI: $K_i = \{i - 1\}$ for all $i \in N$

FI: $K_i = \{1, 2, \ldots i - 1\}$ for all $i \in N$

4.1 Equilibrium with increasing returns to scale

A technology with increasing returns to scale is characterized by $p(k + 1) - p(k) > p(k) - p(k - 1)$ for all k. For such a technology, the vector of benefit factors b can be constructed such that all agents contribute in the unique subgame-perfect equilibrium of the game corresponding to FI, whereas mutual defection can be sustained in a Nash equilibrium of the game induced by NI. More specifically, the equilibrium strategy of each agent in FI is to contribute if and only if she observes full contribution. We achieve this by imposing two conditions on b:

$$b_i \geq \frac{C}{p(n) - p(i - 1)} \qquad \forall i \in N \tag{1}$$

$$b_i < \frac{C}{p(n - 1) - p(0)} \qquad \forall i \in N \tag{2}$$

Condition (1) ensures that each agent has the monetary incentive to contribute if by that she increases the number of contributing agents from the full set of her predecessors to the full set N. Condition (2) is sufficient to guarantee that no agent can increase her payoff by contributing if at least one other agent did not or will not contribute.

Proposition 1. *Conditions (1) and (2) guarantee that all agents contribute in the unique subgame-perfect equilibrium of FI if and only if they observe full contributions.*

Proof. To show that any defection of a single agent suffices to guarantee that all other agents strictly reduce their payoff by contributing, write k for the number of agents other than i that contribute if i contributes. Thus, if i contributes, she obtains $b_i p(k + 1) - C$.

Because $p(\cdot)$ is increasing, i obtains by defecting at least $b_i p(0)$. The change in payoff from defection to contribution is therefore smaller than $b_i[p(k+1) - p(0)] - C$, which, by Condition (2), is negative as long as $k < n - 1$.

It follows directly that, in equilibrium, any defection by an agent in K_i leads to a defection by i. It remains to be shown that the converse is also true, i.e., if all agents in K_i contribute, i contributes as well in equilibrium. First, note that in FI, $i \in K_j$ for all $j > i$, implying that by defecting i leads all agents j to defect as well, thus obtaining a payoff of $b_i p(i-1)$. Conversely, if i contributes, all agents j will also contribute. This can be shown by backward induction. Assuming that all agents j contribute when observing full contributions, i increases her payoff by $[b_i p(n) - C] - [b_i p(i-1)$ by contributing, which is non-negative by Condition (1). Condition (1) also implies that the assumption holds for agent n, hereby completing the backward induction proof. □

As in Winter (2010), Conditions (1) and (2) also ensure that full contribution is a sequential equilibrium in CI.[7] However, there also exist sequential equilibria in which none of the agents contributes. For example, when $s_i = 0$ for all i and all I_i, i.e., all agents defect regardless of their information. The difference between FI and CI is rooted in the beliefs of an agent who observes her immediate predecessor contributing. In the equilibrium of FI, she directly observes that all previous movers have also contributed, whereas in CI she can only deduce this from the observed contribution. When the sequential equilibrium in which all agents defect is considered, it is sequentially rational for the agent to keep her prior belief that unobserved agents have defected and attribute the observed contribution to a tremble.

Nonetheless, in the environment we consider, which corresponds to the optimal mechanism of Winter (2010), we can obtain a stronger result if we impose a weak constraint on rational beliefs:

Proposition 2. *Conditions (1) and (2) guarantee that all agents contribute in the unique sequential equilibrium of CI that satisfies the requirement that all assessments attribute zero probability to all strictly dominated strategies.*[8]

Proof. As shown in the proof to Proposition 1, it is strictly dominated for an agent to contribute if she observes a defection. Therefore, if agent i observes agent $i-1$ contributing, she cannot rationally believe that any agent in K_{i-1} has defected. Applying this argu-

[7] Winter (2010) considered weak implementation of perfect Bayesian equilibria, although the result easily extends to sequential equilibria. Proposition 2 below can be extended to prove a full-implementation result.

[8] This requirement was raised by Kreps and Wilson (1982, Section 8) in their paper that introduced the notion of sequential equilibria. It is implied by many refinements of sequential equilibria such as justifiable equilibrium (McLennan, 1985), intuitive criterion (Cho and Kreps, 1987), perfect sequential equilibrium (Grossman and Perry, 1986), and stable set (Kohlberg and Mertens, 1986).

ment recursively, we find that i believes that all previous movers have contributed. Now the backward induction can be applied as in the proof to Proposition 1. $\square$

In the unique equilibria of FI and CI described in propositions 1 and 2, zero contributions are ruled out as an equilibrium essentially by the decision of the first mover to contribute, thus triggering a chain of contributions by all agents. Conversely, in NI it is impossible to eliminate the equilibrium in which none of the agent contribute, due to the lack of information flow between agents.[9]

4.2 *Equilibrium with linear technology*

A linear technology $p(k)$ is defined as one in which the marginal contribution $d = p(k+1) - p(k)$ is fixed for any k. It follows that a selfish money-maximizing agent contributes iff $b_i \geq C/d$. Since both C and d are exogenous, each such agent has a dominant strategy either to contribute or to defect. In other words, the actions of the other agents do not affect the monetary incentives of an agent, and thus the equilibrium analysis is not affected by the information agents acquire about the decisions made by previous movers. More specifically, if $b_i < C/d$ for all $i \in N$ and $\sum_{i \in N}(b_i d) > C$, the game is a social dilemma, in which all agents have a dominant strategy to defect, but the outcome of full contributions Pareto-dominate the outcome of zero contributions.

Now consider behavior when agents have an intrinsic tendency for reciprocity. We choose to model reciprocity tendencies in line with the principle of *concern withdrawal* (Charness and Rabin, 2002). The model is designed to capture the following principles: (a) agents are willing to pay some monetary cost in order to benefit their group; (b) some agents are more intrinsically cooperative than others; and (c) this preference for cooperation is withdrawn if the other members of the group (are known to have) misbehaved.[10]

For analytical simplicity, we incorporate reciprocal preferences into our model by assuming that the cost of contribution for agent i who did not observe any defection is $C - \theta_i$, where $\theta_i \in \mathbb{R}_+$ is the individual psychological reduction in the cost of cooperation and is distributed in the population according to a continuous and differentiable cumulative distribution F with positive density everywhere. On the other hand, if agent i did observe defection, she withdraws her concern for the group and maximizes her monetary payoff. This assumption allows us to draw several conclusions, the first of which is reflected in Proposition 3:

[9] There is still an equilibrium in which all agents contribute. Goerg et al. (2010) have shown that the existence of a Pareto- and risk-dominated equilibrium in which no agent contributes is enough to significantly harm coordination and reduce contribution levels.

[10] More general models of reciprocity in extensive games were developed by, e.g., Dufwenberg and Kirchsteiger (2004) and Falk and Fischbacher (2006). However even these formidable efforts are unable to analyze a game with imperfect information across stages, as in our CI treatment. Developing a general model is thus beyond the scope of the current study.

Proposition 3. *The probability of contribution in NI under a linear technology and with reciprocal preferences is given by* $1 - F(C - b_i a)$.

See the appendix for the proof. Note that contributions are increasing in the benefit factor b_i. The effect of transparency can now be characterized thus:

Proposition 4. *With reciprocal preferences, expected contributions in FI and CI are higher than NI for first movers and vice versa for last movers.*

We defer the detailed proof to the appendix. However, the intuition is straightforward. According to the principle of concern withdrawal, agents in FI and CI who observe defection never contribute while those who do observe defection are as likely to contribute as their counterparts in NI. Thus, the positive effect of transparency is mediated by the implicit threat of future movers to reciprocate defection with defection. This threat diminishes along the chain, and is non-existent for the very last mover. The negative effect of reciprocity is given by the probability of an agent observing defection, which is non-existent for the first mover and increases along the chain. In other words, with increased transparency, a first mover only faces increased incentives due to (anticipation of) positive reciprocity whereas a last mover only faces diminished incentives due to negative reciprocity. In general, the negative effect of reciprocity increases along the chain whereas the positive effect decreases, although the latter is subject to restrictions on individual differences in the benefit factor b_i.

We see that reciprocal preferences alter the equilibrium analysis under a linear technology. To complete the picture, note that the analysis of FI and CI with increasing returns to scale remains unchanged. Condition (1) still holds for agents who do not observe defection when C is replaced with $C - \theta_i < C$. Condition (2), in turn, trivially holds for agents who observe defection. Proposition 1 therefore remains valid with reciprocal preferences.

5 Experimental design and procedure

Participants in the experiment interacted in groups of four in a repeated public goods game described in Section 4. To test our hypotheses regarding the interplay of information and technology in voluntary public goods provision, we manipulated the technology and the level of transparency to create a 3x2 between-subject design. The three transparency treatments reflect the three information structures NI, CI and FI, whereas the two technology treatments are designed to be either with increasing returns to scale (**IRS**) or linear (**LIN**). The experimental technologies are presented in Table 1.

As can be seen in the table, the output in both treatments is increasing in the number of contributors, with $p(0) = 180$ and $p(4) = 500$. The intermediate values vary with

Table 1: Experimental technologies

Technology	# of contributors				
	$k=0$	$k=1$	$k=2$	$k=3$	$k=4$
IRS	180	190	220	310	500
LIN	180	260	340	420	500

the treatment, with the return from a single contribution increasing from 10 to 190 in IRS, compared to LIN, in which the return from each single contribution is fixed at 80.

The cost of contribution was fixed in all treatments to be $C = 650$. In accordance with Conditions (1) and (2), the benefit factor was fixed at $b_i = 4$ for the first and second movers, and at $b_i = 5$ for the third and fourth movers.[11] Therefore, the monetary incentives in the LIN technology define a linear public good in which every agent loses money by contributing whereas her payoff is higher if all four agents contribute compared to the equilibrium outcome (cf. Section 4.2). The six treatments and the pure equilibria for selfish money-maximizing agents described in Section 4 are summarized in Table 2.

Table 2: Equilibria in the different treatments

	IRS	**LIN**
NI	(0,0,0,0),(1,1,1,1)	(0,0,0,0)
CI	(1,1,1,1)	(0,0,0,0)
FI	(1,1,1,1)	(0,0,0,0)

Note: 0=defect, 1=contribute.

The sessions were conducted in June 2010 at the computerized Max Planck Experimental Laboratory in Jena. Each session was composed of 32 participants interacting in 8 groups, all in the same treatment. For each of the six treatments we ran two sessions, i.e., 12 sessions + 1 pilot with 400 participants in total. The participants were students at the Friedrich Schiller University of Jena. The experiment was programmed using z-Tree (Fischbacher, 2007), and the invitation of participants was managed using ORSEE (Greiner, 2004), which guaranteed that no subject participated in more than one session. Experimental earnings were specified in Experimental Currency Units (ECU), which were converted to euros at the end of the experiment at a conversion rate of 150 ECU = 1€. Final payoffs ranged from 5€ to 18€, with an average of 11.73€ per participant.

[11]The mean marginal per-capita return (MPCR) is therefore approximately 0.55.

At the beginning of the experiment, participants read the instructions in private, after which the instructions were read out aloud to ensure common knowledge, and additional questions were answered privately. Participants were not aware of the existence of other technology and information treatments.[12] Once all participants had indicated that they understood the instructions, a practice phase commenced, in which participants were given the opportunity to simulate the experiment by playing in all four roles repeatedly.

At the beginning of the experimental phase, participants were randomly assigned into groups of four. Each group interacted over twelve periods in a partners design. At the beginning of each period, the participants in the group were (re)assigned to roles, determining the order of moves within the period (denoted by the letters A, B, C, D).[13] Each participant, in her turn, received information about previous moves within the period according to the experimental treatment (NI, CI or FI) and decided whether to contribute or not. An on-screen calculator was provided to help the participants work out possible payoffs for different decisions (see screenshot in the appendix). Next, the participants were asked to state their expectations about the decisions of the other group members, excluding those they were informed about. Finally, the participants were informed about the number of contributors in their group and of their own period earnings.

At the end of the experiment, one period was randomly selected for payoff. An additional 150 ECU were awarded for a correct expectation, randomly chosen from the expectations made in the non-payoff periods. Before leaving the lab participants were asked to fill out a short questionnaire and were paid out individually and privately.

6 Results

We start our analysis by looking at the effects of transparency on contribution levels in the two technology treatments, at the individual and group levels and by roles. We proceed by analysing the strategies employed by our participants, specifically the existence of conditional cooperative strategies under partial and full transparency in the two technology treatments. Finally, we look at whether beliefs about past moves in the CI treatment are updated according to belief in conditional cooperation of the intermediate players.

[12] We used a labor framing following Goerg et al. (2010). A translation of the German instructions is provided in the appendix.

[13] To keep the procedure consistent, we employed the same sequential protocol in all treatments, including NI, which is equivalent to a simultaneous-moves game.

6.1 Contribution levels

The average contribution levels by information treatment and period are shown in Figure 1. First, let us focus on the top panel, representing the IRS treatments. We see that, contrary to the equilibrium prediction, contribution levels start out highest in the NI treatment, with FI performing considerably worse than the other two treatments. Nonetheless, there is considerable increase in contributions in the two information treatments accompanied by a sharp decrease in the baseline NI treatment. By the sixth period, contribution levels stabilize with, on average, around three out of four contributors in CI and FI and under two out of four contributors in NI.

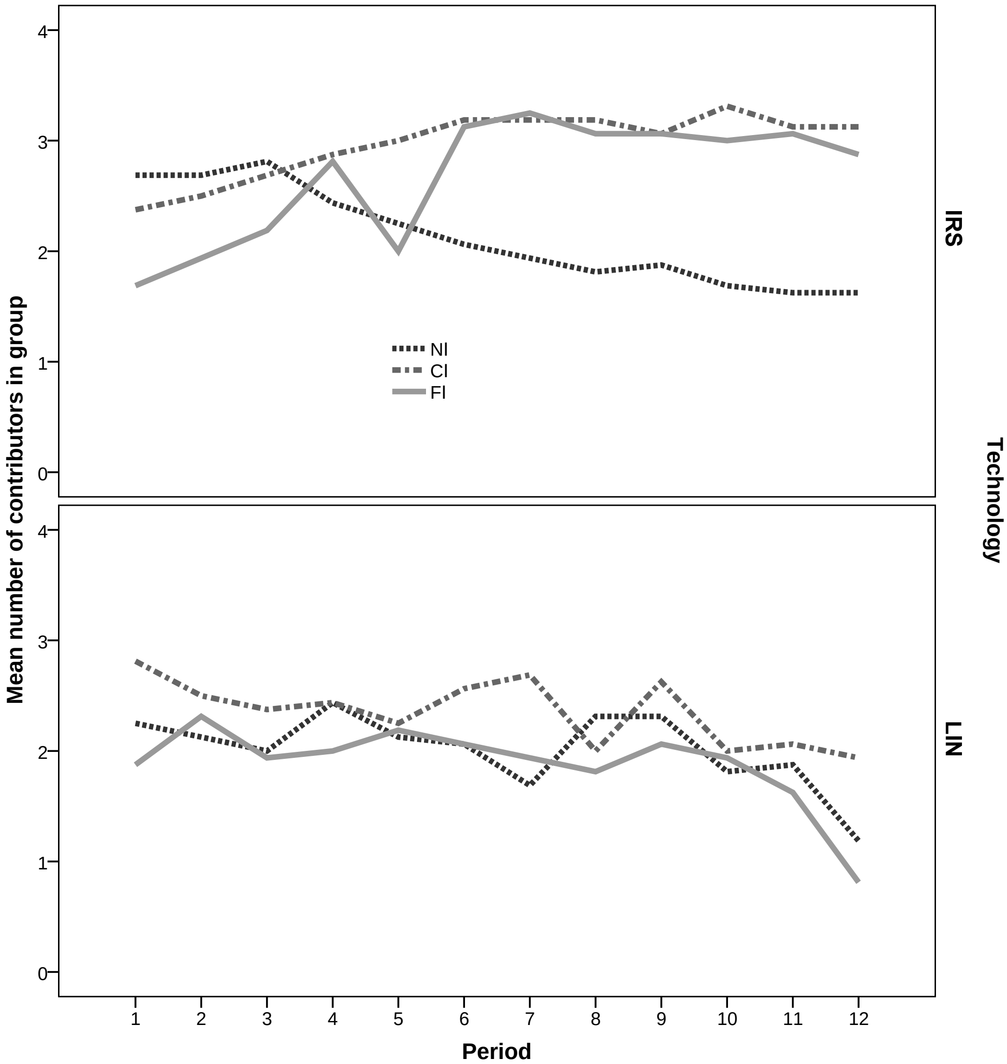

Figure 1: Mean contributions

Table 3: Mean contribution levels

	IRS			LIN		
	NI	CI	FI	NI	CI	FI
All periods	0.53	0.74	0.67	0.50	0.59	0.47
	(0.09)	(0.07)	(0.07)	(0.05)	(0.05)	(0.05)
Periods 1-6	0.62	0.69	0.57	0.54	0.62	0.52
	(0.08)	(0.07)	(0.07)	(0.05)	(0.06)	(0.05)
Periods 7-12	0.44	0.79**	0.76*	0.47	0.55	0.42
	(0.11)	(0.08)	(0.09)	(0.05)	(0.06)	(0.06)
Last period	0.41	0.78**	0.72*	0.30	0.48†	0.20
	(0.11)	(0.10)	(0.11)	(0.05)	(0.09)	(0.06)

Note: Standard errors in parentheses.

*,** denote significant difference from NI at the 10 and 5 percent levels, respectively, two-sided Mann-Whitney test.

† Mean contributions in the last period are significantly higher in CI than in FI at the 5 percent level, two-sided Mann-Whitney test..

The average contribution levels in the IRS treatment are presented on the left-hand side of Table 3 for the entire experiment as well as for blocks of 6 periods and for the very last period. Non-parametric tests confirm the pattern evident in Figure 1. Although overall contribution levels do not differ between information treatments, they are significantly higher than NI in both other treatments for the second half of the experiment. This pattern is also confirmed in the mixed-effects probit regression shown in column (1) of Table 4. Contributions significantly decline in NI and significantly increase in CI ($\beta = 0.090$, $SE = 0.018$, $p < 0.001$) and in FI ($\beta = 0.124$, $SE = 0.017$, $p < 0.001$).[14] The mean contribution observed in FI in the first period is significantly lower than that observed in NI ($\beta = 1.315$, $SE = 0.529$, $p = 0.013$) but not than that in CI ($\beta = 0.702$, $SE = 0.527$, $p = 0.183$). The difference between the two other treatments is also not significant ($\beta = 0.613$, $SE = 0.533$, $p = 0.250$). We interpret this adverse effect of full transparency as evidence for the immediate effect of negative reciprocity. Conversely, the positive effects of reciprocity require the first movers to apply high-level strategic thinking and belief in the rationality of their followers, and therefore these effects become evident only following a learning period.

Observation 1. *Contributions under increasing returns to scale converge towards the equilibrium predictions with time. Full transparency leads to lower contribution rates at the beginning of the experiment, but increase with time, while contribution rates under zero transparency decrease. Partial transparency performs at least as well as full*

[14]All coefficients reported in the text are based on a test on the corresponding linear combinations of coefficients estimated following the regressions reported in the tables.

transparency.

Thus, the data are consistent with our Hypotheses 1 and 2. Columns (3) and (4) in Table 4 apply a similar analysis on the group level to reveal the dynamics behind the effects. As is evident in the top panels of Figure 2, the proportion of groups that achieve full cooperation in the first period is similar in all information treatments. In NI, this proportion remains stable throughout the experiment, and, in fact, from period 5 onwards there is no change in the identity of the fully cooperative groups. Thus, groups that, by chance, consist of cooperative individuals manage to maintain cooperation over time. The decline in average contributions in this treatment is due to the increase in the proportion of groups in which no member contributes. The existence of free riders in a group leads early contributors to defect in later periods.

Conversely, in the two information treatments, it is the free riders in the mixed groups that learn to cooperate, in line with the equilibrium prediction, so that groups that start out with heterogeneous contributions become fully cooperative within a few periods. Thus, when free riders and cooperative types find themselves in the same group, each type pulls in its direction, and the one type backed by the monetary incentives triumphs. Moreover, some of the groups that started out with zero contributions in FI learn to overcome the initial hurdle, as observed in the decrease in proportion of zero-contribution groups in this treatment ($\beta = -0.074$, $SE = 0.036$, p=0.037). This proportion is stable in CI ($\beta = 0.004$, $SE = 0.040$, p=0.921).

Observation 2. *Under increasing returns to scale, fully cooperative groups tend to stay cooperative over time regardless of the information structure. The decrease in contributions when actions are not observed, and the increase in contributions with partial and full transparency, are mainly due to groups with heterogeneous contributions in the first period learning to converge to the equilibrium.*

Compared with the strong effects of information observed in the IRS treatments, no significant effect of the information treatments on overall contributions is found in LIN, as can be seen in the bottom panel of Figure 1, the right-hand side of Table 3, and columns (5), (7) and (8) in Table 4. However, there is a weakly significant tendency for more zero-cooperation in groups when the full history is observed within the period. A weak but significant negative time effect is evident in all information treatments, with a sharp decrease in contributions in NI and FI, which is not evident under CI (although the difference in the last period is significant only when comparing FI and CI). Nonetheless, an analysis of the contribution decisions made by the participants when playing in the different roles reveals significant patterns that differ according to the information structure in line with the predictions based on the assumption of reciprocal preferences.

Table 4: Contribution decisions

	IRS				LIN			
	(1) Individual contribution	(2) Individual contribution	(3) Group full contribution	(4) Group zero contribution	(5) Individual contribution	(6) Individual contribution	(7) Group full contribution	(8) Group zero contribution
Period[a]	-0.136***	-0.140***	-0.002	0.312***	-0.039***	-0.042***	-0.057	0.052
	(0.018)	(0.019)	(0.053)	(0.063)	(0.014)	(0.014)	(0.042)	(0.043)
CI	2.090***		3.658***	-1.842***	0.243		0.493	0.344
	(0.533)		(1.120)	(0.636)	(0.228)		(0.525)	(0.429)
FI	1.797**		3.255***	-1.822***	-0.147		0.039	0.795*
	(0.527)		(1.087)	(0.615)	(0.229)		(0.552)	(0.411)
Period[a]x CI	0.225***	0.233***	0.229***	-0.308***	-0.000	0.003	-0.019	0.042
	(0.026)	(0.026)	(0.072)	(0.074)	(0.020)	(0.020)	(0.054)	(0.060)
Period[a]x FI	0.259***	0.266***	0.238***	-0.386***	-0.008	-0.009	-0.011	0.005
	(0.025)	(0.026)	(0.069)	(0.073)	(0.020)	(0.020)	(0.058)	(0.053)
Second mover		-0.043				0.015		
		(0.176)				(0.138)		
Third mover		0.466**				0.729***		
		(0.176)				(0.139)		
Fourth mover		0.477**				0.479***		
		(0.175)				(0.136)		
CI x								
First mover		2.667***				0.724***		
		(0.572)				(0.267)		
Second mover		2.510***				0.651**		
		(0.570)				(0.267)		
Third mover		1.819***				-0.053		
		(0.567)				(0.265)		
Fourth mover		1.600***				-0.258		
		(0.564)				(0.264)		
FI x								
First mover		2.310***				0.557**		
		(0.563)				(0.268)		
Second mover		2.134***				0.416		
		(0.562)				(0.268)		
Third mover		1.487***				-0.691***		
		(0.559)				(0.267)		
Fourth mover		1.384***				-0.913***		
		(0.558)				(0.270)		
Constant	-0.387	-0.626	-1.753**	0.083	-0.206	-0.529***	-1.983***	-1.384***
	(0.373)	(0.399)	(0.792)	(0.439)	(0.161)	(0.189)	(0.411)	(0.324)
Observations	2304	2304	576	576	2304	2304	576	576

Notes: Probit regressions with random effects for groups. Standard errors in parentheses.

[a] The last period is taken as the baseline.
*,**,*** denote significance at the 10, 5 and 1 percent levels, respectively.

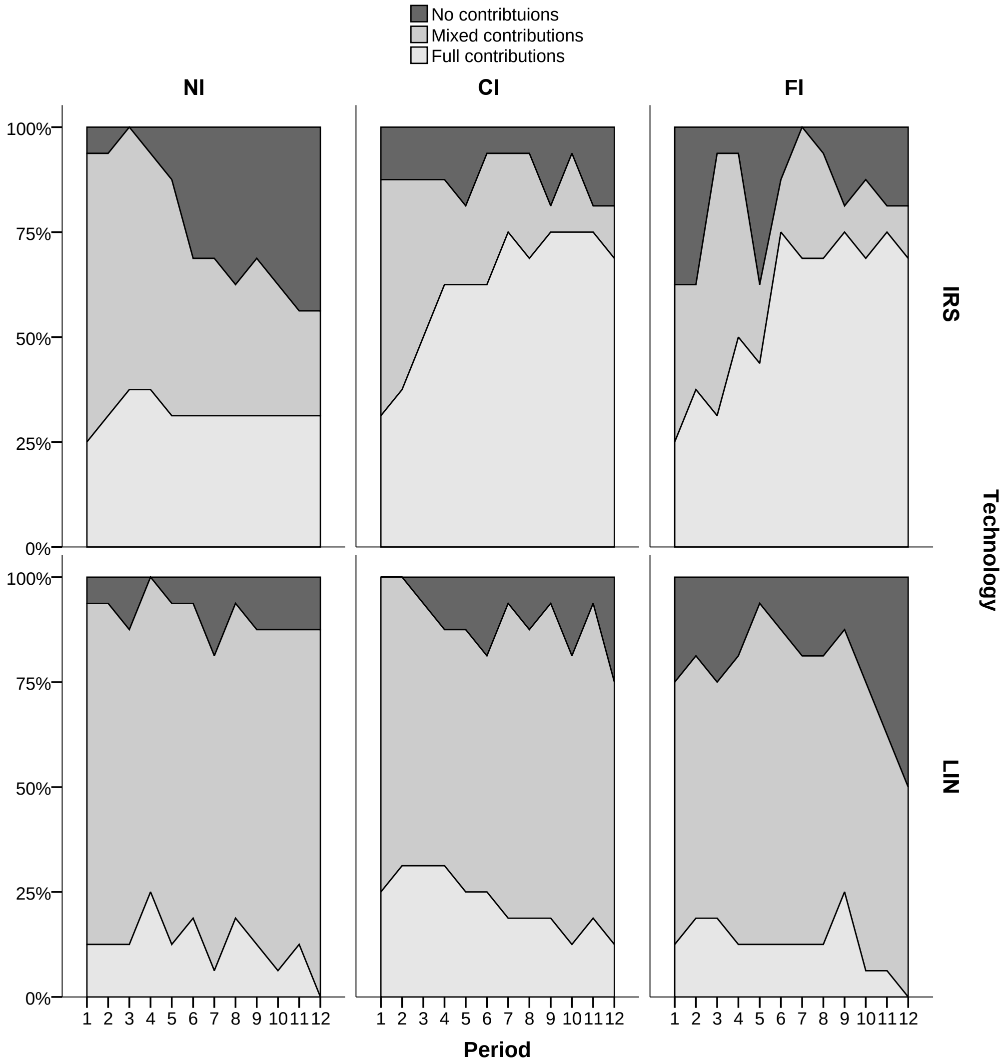

Figure 2: Group composition

Mean contribution rates by role for all treatments are presented in Figure 3. In line with our Hypothesis 4, the positive effects of transparency in the LIN treatments diminish along the chain, becoming negative for the late movers. The regression in columns (6) in Table 4 bears out this effect. Moreover, a similar trend is observed in column (2), corresponding to the IRS technology. First, note that the last two movers, who have a higher benefit factor than the first two, are more likely to contribute, in line with the prediction derived from the assumption of reciprocal preferences (Proposition 3). Second, and of greater interest, are the effects of the two information treatments by the different roles. In IRS, all coefficients are positive and highly significant, indicating that participants

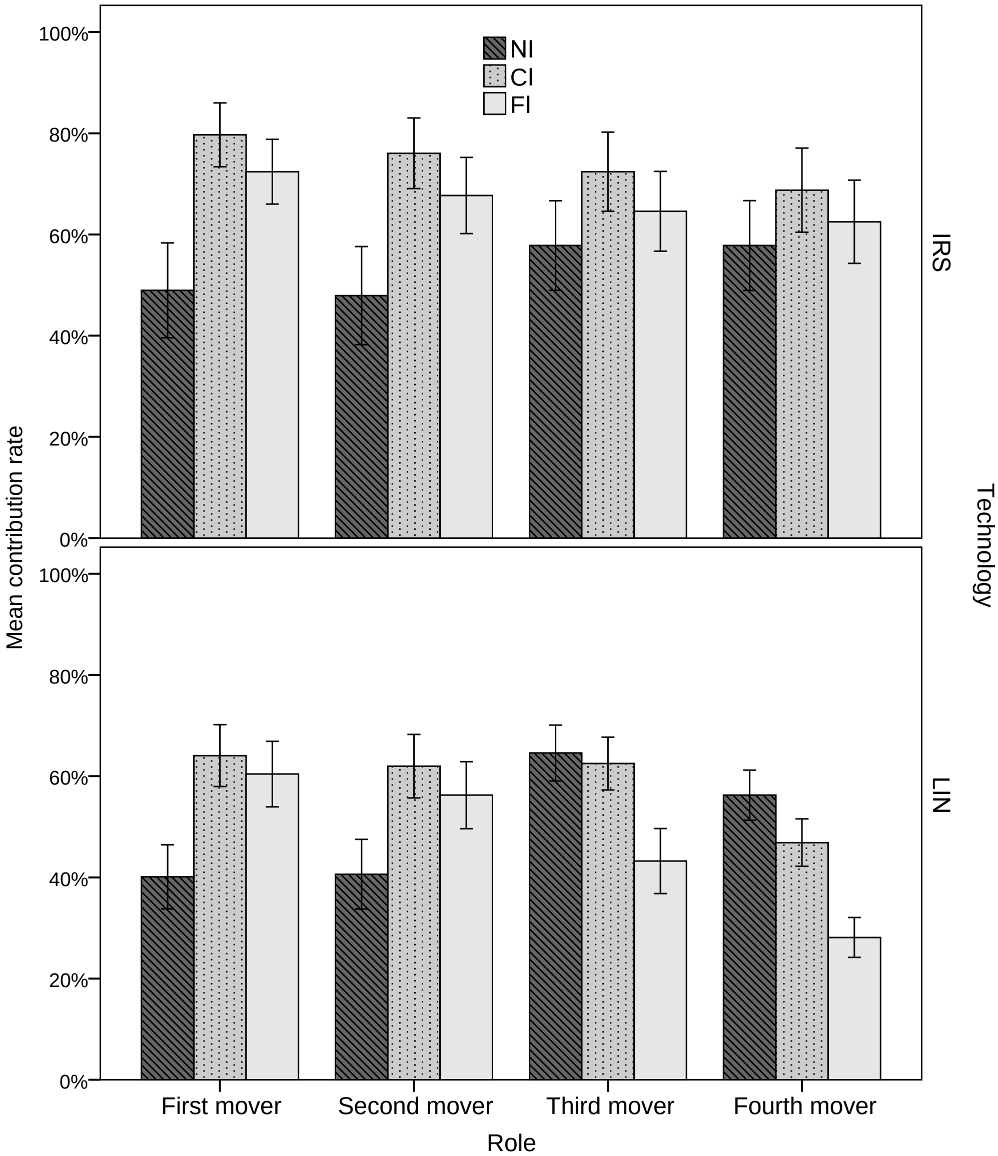

Figure 3: Contributions by role

are more likely to contribute under both partial and full transparency.[15] However, the coefficients decrease in value along the chain, with the difference in coefficients between the second and third movers being significant ($\beta = -0.691$, $SE = 0.251$, $p = 0.006$ in CI; $\beta = -0.647$, $SE = 0.241$, $p = 0.007$; $p \geq 0.372$ for all other comparisons between

[15]Column (2) in Table 4. Note that the coefficients relate to the effects at the end of the experiment. Non-parametric tests for group averages over all periods yield significant results only for the comparison of NI and CI for the first and second movers ($p = 0.019$ and $p = 0.053$, respectively, two-sided Mann-Whitney test).

two consecutive roles).[16]

Moving to the LIN treatment presented in column (6) in Table 4, the contributions levels of the two late movers do not differ significantly between NI and CI and are significantly *lower* in FI. The difference between FI and CI is also significant ($\beta = 0.637$, $SE = 0.267, p = 0.017$ for the third mover; $\beta = 0.654, SE = 0.279, p = 0.015$ for the fourth mover). We conclude that for early movers, CI significantly outperforms NI while not doing worse than FI. For late movers, on the other hand, CI outperforms FI, while not doing significantly worse than NI.[17] Thus, we not only find support for Hypothesis 3, the data reveal a similar effect in IRS and, most importantly, an advantage of CI over FI. Unlike in FI, the detrimental effects of a single defection in CI can be overturned by an agent who wishes to establish cooperation with her followers by contributing, even if she believes they would withhold contributions after observing a single defection.

It is worth noting that, in principle, the opposite effect to that outlined above could have also occurred. That is, a single defection following a history of cooperation would be more detrimental to future cooperation in CI than in FI, leading to higher contributions by late movers in FI.[18] This, however, creates increased incentives to follow cooperation with cooperation in CI. To illustrate, consider the case in which the first two movers cooperate. In CI, this history of cooperation is invisible to the fourth mover, who conditions her decision on the observed action of the third mover, contributing 58% of the time when the third mover contributed and only 28% of the time otherwise. In FI, in comparison, fourth movers who observe the first two movers contributing contribute approximately 43% of the time regardless of the third mover's action. Therefore, FI appears to facilitate future cooperation after a history of cooperation followed by a single defection. Nonetheless, such histories are less likely to occur in CI, as we observe 80% contributions by third mover following a history of cooperation compared to 65% in FI, where such contributions do not affect the fourth mover's decision.

Observation 3. *The positive effects of increased transparency mostly affect early movers, whereas the negative effects mainly affect late movers. With increasing returns to scale, where positive reciprocity is supported by the monetary incentives, the positive effects outweigh the negative. In the social dilemma, however, contributions of late movers are reduced when there is too much transparency. Partial transparency thus provides the*

[16]The decrease in contributions along the chain with full information was also observed by Figuieres et al. (2012).

[17]This conclusion is fully supported by non-parametric two-sided Mann-Whitney tests for the group averages over all periods presented in Figure 3. For the first two movers, CI leads to contribution rates higher than NI ($p = 0.021$ and $p = 0.039$, respectively) but not significantly different from those under FI ($p = 0.776$ and $p = 0.544$, respectively). For the third and fourth movers, contributions under CI are significantly higher than those under FI ($p = 0.035$ and $p = 0.006$, respectively) but not significantly different from those under NI ($p = 0.834$ and $p = 0.303$, respectively).

[18]We thank an anonymous reviewer for raising this point.

best environment for cooperation, benefiting from the positive effects of transparency, while avoiding its detrimental effects.

6.2 Reciprocal strategies

The theoretical analysis reveals that cooperation can be sustained by reciprocal strategies, i.e., when all agents contribute if and only if everyone they observe has contributed, with both partial and full transparency. In IRS, these strategies are supported by the monetary incentives as the equilibrium strategies. In LIN, however, such reciprocal *strategies* should exist only due to reciprocal *preferences*. The regression models presented in Table 5 study the effect of observed cooperation on contributions. We find that, in LIN, participants are significantly more likely to contribute if they observe contribution. These findings support the hypothesis that (some of) our participants are intrinsically conditional cooperators, i.e., have reciprocal preferences. The effect over observed full cooperation is stable over time.

Conditional cooperation is markedly enhanced in IRS, where it arises directly from the monetary incentive structure. Furthermore, the effect of the technology slightly increases over time, as participants gain experience with this structure.[19]

Observation 4. *Conditional cooperation is evident even in the social dilemma, consistent with underlying reciprocal preferences. Conditional cooperation is considerably enhanced when supported by the monetary incentives.*

6.3 Beliefs about unobserved previous movers

The theoretical analysis in Section 4 predicts that an information chain is as efficient as full transparency in facilitating cooperation in our setup. The crux of this result is that a contribution made by the immediate predecessor signals full contributions in the past. To test whether our participants indeed made this inference, we look at the effect of observed contributions on beliefs about previous movers in CI.[20] The results of regressions by the role of the observing and unobserved agents are presented in Table 6. We see that late movers are indeed more likely to believe that the early movers have contributed if the observed intermediate agent has contributed, indicating a belief in conditional cooperation of others. This effect is significant in LIN but is considerably enhanced in IRS,

[19]The effect of time may be underestimated, as in the second part of the experiment most groups become homogeneous, so that their members either only observe cooperation or only observe defection, leaving no room for conditional cooperation to manifest itself.

[20]A graphical summary of the accuracy of all of the elicited beliefs across treatments and roles is provided in the appendix.

Table 5: Conditional cooperation

	CI	FI
Period[a]	-0.036	-0.079***
	(0.027)	(0.022)
IRS	-0.454	-0.133
	(0.453)	(0.358)
Period[a] x IRS	0.012	0.068*
	(0.053)	(0.041)
Observing full contributions	0.824***	1.109***
	(0.223)	(0.235)
Observing full contributions x IRS	2.126***	2.163***
	(0.485)	(0.459)
Observing full contributions x Period[a]	0.002	0.049
	(0.034)	(0.034)
Observing full contributions x IRS x Period[a]	0.119*	0.122**
	(0.064)	(0.061)
Constant	-0.502**	-1.045***
	(0.208)	(0.190)
Observations	1152	1152

Notes: Probit regressions with random effects for groups. Standard errors in parentheses.
[a] The last period is taken as the baseline.
*,**,*** denote significance at the 10, 5 and 1 percent levels, respectively.

where reciprocal strategies are expected in equilibrium.[21] Thus, our final observation mirrors the previous observation:

Observation 5. *Beliefs in conditional cooperation are evident even in the social dilemma, but are considerably enhanced when supported by the monetary incentives.*

7 Conclusion

This paper studies information chains in voluntary contributions to public goods and their effect on individual and group performance. We analyze an environment designed to be conducive to cooperation under full transparency and increasing returns to scale and show theoretically that this environment is also predicted to induce cooperation in

[21] Note, however, that conditional cooperation and belief therein is manifested only if the observed mover sometimes plays *out of equilibrium*.

Table 6: Beliefs about unobserved previous movers in CI

	Third mover's belief about	Fourth mover's belief about	
	First mover	First mover	Second mover
Period[a]	0.017	-0.053	0.048
	(0.053)	(0.049)	(0.054)
IRS	-2.605	-0.770	-1.254
	(1.668)	(0.669)	(0.823)
Observing contribution	1.879***	0.909**	1.767***
	(0.453)	(0.396)	(0.454)
Observing contribution x	0.017	0.089	-0.059
Period[a]	(0.070)	(0.062)	(0.072)
IRS x	-0.257	0.049	-0.064
Period[a]	(0.181)	(0.086)	(0.105)
Observing contribution x	3.567**	1.669**	2.032**
IRS	(1.739)	(0.776)	(0.959)
Observing contribution x	0.312	-0.075	0.142
IRS x	(0.195)	(0.109)	(0.130)
Period[a]			
Constant	-0.647*	-0.178	-0.420
	(0.354)	(0.324)	(0.341)
Observations	384	384	384

Notes: Probit regressions with random effects for groups. Standard errors in parentheses.

[a] The last period is taken as the baseline.

*,**,*** denote significance at the 10, 5 and 1 percent levels, respectively.

the unique equilibrium that emerges under an information chain, conditional on a weak epistemic requirement that agents (are commonly known to) strongly believe that others never play dominated strategies.

We designed an experiment to test this insight and extended the experimental investigation to test the effects of the information chain in a comparable linear public goods game. The results support the theoretical predictions, as cooperation in the information chain is weakly higher than in the full-transparency environment. We find that the effects of transparency emerge quickly over time, as agents learn to trust their peers to understand the incentive structure.

Behavior and beliefs in the linear public good are consistent with reciprocal strategies, which have the potential to lead to higher contributions as transparency increases. However, when the hypothesized intrinsic reciprocal preferences are not complemented by the monetary incentives, we do not observe the sharp effect found under increasing returns to scale. An analysis of behavior along the chain of agents is in line with the conflicting effects of transparency-induced reciprocity. Transparency is found to have significant positive effects on agents who are mainly observed, but negative effects on agents who mainly observe others.[22]

The importance of transparency for voluntary contributions to public goods has been acknowledged in the theoretical literature (e.g, Andreoni and Samuelson, 2006; Che and Yoo, 2001; Marx and Matthews, 2000; Mohnen et al., 2008; Varian, 1994) and studied both in the field (e.g., Falk and Ichino, 2006; Heywood and Jirjahn, 2004) and in the lab (e.g., Clark and Sefton, 2001; Gächter et al., 2010; Nosenzo and Sefton, 2011). The above studies focused on full transparency, looking at how transparency can be utilized to increase cooperation by way of conditionally cooperative strategies. To this body of literature, we introduce the notion of partial transparency, as manifested in the information chain, as a way to extract the potential for cooperation inherent in transparency while mitigating the detrimental effects associated with full transparency, which have been largely neglected so far.[23]

Our results suggest that an information chain is not only sufficient to induce cooperation (as in Winter, 2010) but also has the potential to surpass the benefits of full transparency. Full transparency is shown to perform almost as well as partial transparency when there are strong positive externalities between agents and sufficient opportunity for learning. However, in early rounds, and when the externalities are weak, the relative advantage of partial transparency increases, in particular with respect to agents who are positioned later in the chain.

Our conclusions have practical implications across several domains. First, fundraisers know that providing information about past donations is instrumental in attracting new donations. Our results suggest that a full revelation of the history may be harmful. In comparison, reporting the donations over a fixed time window (e.g., a week, a month, etc.) may have the advantage of avoiding any lasting effects of periods of low donations.[24]

Second, the study of institution design aimed at increasing voluntary provision of public goods has looked at the efficacy of incorporating reputation effects (e.g., Milinski et al., 2006; Rockenbach and Milinski, 2006). However, the existing studies focused on indirect reciprocity, and thus neglected the potential effects on the observing agents. Future studies should acknowledge both the positive and negative aspects of transparency and seek a balance between the two.

[22] An interesting extension to this line of research would be to study behavior of intermediate agents as the length of the chain increases.

[23] Bag and Pepito (2011) have shown that outcome transparency can reduce contributions in a two-period two-players production game, in which effort is fully observed. The notion of partial transparency is, however, irrelevant to games of two players (which have also been the focus of the majority of the theoretical and empirical studies mentioned above).

[24] It is also possible to strategically choose the time window to maximize the observed donations. However, potential donors may resent such manipulation, if revealed.

Finally, our conclusions go beyond the domain of voluntary public good provision. As noted in our theoretical analysis, team production can generate a public good. Labor economists have dedicated considerable effort to studying production in a team and to ascertaining optimal ways to incentivize multiple agents to exert effort in team environments.[25] Firm-controlled workplace architecture can thus be designed to utilize the incentivizing potential of transparency. For example, it has been suggested that co-location of workers is likely to increase productivity (Heywood and Jirjahn, 2004; Teasley et al., 2002). Our results suggest that some partitioning of workers is advisable to contain the effects of 'rotten apples'. In the case of globalized production processes, where different parts of the production chain may be scattered across different continents, the firm has much control over the information that different workers have on the output of others. Conditional strategies in the work environment can also be contractually implemented rather than be allowed to arise from the flow of information. The design of contracts should take into account that contracts that allow to condition on peer performance may be inferior to more restricted contracts.

In sum, we find that, in line with previous theoretical and empirical findings, increased transparency generally has a beneficial effect on voluntary contributions to public goods. Although some studies failed to find such an effect, to the best of our knowledge this is the first experimental study to find that transparency has some detrimental effect on cooperation (in early periods and for late movers). More importantly, we find that an information chain can be effective in balancing the advantages and drawbacks of transparency. Furthermore, we look at the way in which transparency interacts with the technology to influence the balance between positive and negative reciprocity. This paper has thus established the beneficial potential of partial-transparency structures, in particular that of information chains, under different technologies. Future research is required to test the generality and boundaries of our conclusions with regard to different environments. For example, when contributions are continuous or incremental, or with larger groups.

[25] See, e.g.,Che and Yoo (2001); Goerg et al. (2010); Hamilton et al. (2003); Holmstrom (1982); Lin (1997); Mohnen et al. (2008); Winter (2004, 2006).

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Appendix A: Proofs

Proposition 3. *The probability of contribution in NI under a linear technology and with reciprocal preferences is given by* $1 - F(C - b_i a)$*.*

Proof. To simplify notation, denote by $w(i, k, F)$ the probability that exactly k agents other than i contribute in equilibrium. Agent i will contribute iff

$$b_i \sum_{k=1}^{n} [p(k)w(i, k-1, F)] - (C - \theta_i) \geq b_i \sum_{k=1}^{n} [(p(k-1)w(i, k-1, F)] \, .$$

Rearrange to obtain:

$$\theta_i \geq C - b_i \sum_{k=1}^{N} w(i, k-1, F)(p(k) - p(k-1)). \tag{A.1}$$

Substitute a for the constant slope of the production function $p(k) - p(k-1)$ to see that the summation adds up to 1. The inequality thus reduces to:

$$\theta_i \geq C - b_i a,$$

so that the probability of agent i contributing in equilibrium is

$$Prob^{NI}(s_i = 1) = 1 - F(C - b_i a). \tag{A.2}$$

□

Proposition 4. *With reciprocal preferences, expected contributions in FI and CI are higher than NI for first movers and vice versa for last movers.*

Proof. Denote by q_j the probability that agent j contributes in equilibrium conditional on not observing any defection. Let $g(i)$ be the expected productivity in equilibrium if all agents up to and including i contribute, given by

$$\begin{aligned} g(i) = p(i)(1 - q_{i+1}) + p(i+1)[q_{i+1}(1 - q_{i+2})] + \cdots \\ + p(n-1) \prod_{j=i+1}^{n-1} q_j \cdot (1 - q_n) + p(n) \prod_{j=i+1}^{n} q_j. \end{aligned} \tag{A.3}$$

Note that $g(i)$ has two important properties. First, as i increases, more agents are taken to be contributing, so that $g(i)$ is increasing in i. Second, $g(i)$ is strictly larger than $p(i)$ for $i < n$. If $i = n$, then $g(i) = p(i)$.

Agent i will not contribute if she observes defection.[26] Otherwise she will contribute iff

$$b_i g(i) - (C - \theta_i) \geq b_i(p(i-1)),$$

so that the probability of agent i contributing after not observing any defection is

$$1 - F(C - b_i(g(i) - p(i-1))). \tag{A.4}$$

Since $g(i) \geq p(i)$, the probability of contribution in FI and CI conditional on no previous defections, given by (A.4), is larger than the (unconditional) probability of contribution in NI, given by (A.2). The two probabilities are equal iff $i = n$.

It remains to ascertain the ex-ante probability of agent i not observing any defection, which we shall denote by $f(i)$. This is simply

$$f(i) = \begin{cases} 1 & \text{if } i = 1 \\ \prod_{j=1}^{i-1} q_j & \text{otherwise.} \end{cases} \tag{A.5}$$

Note that $f(i)$ is trivially decreasing in i.

Put together, the probability that player i will contribute in equilibrium is given by

$$Prob^{FI/CI}(s_i = 1) = f(i)\left[1 - F(C - b_i(g(i) - p(i-1)))\right], \tag{A.6}$$

which is decreasing in i.

For first movers, $f(i) = 1$ and $g(i) > p(i)$, so that $Prob^{FI/CI}(s_i = 1) > Prob^{NI}(s_i = 1)$. For last movers, $f(i) < 1$ and $g(i) = p(i)$, hence $Prob^{FI/CI}(s_i = 1) < Prob^{NI}(s_i = 1)$. The difference between the probabilities,

$$\begin{aligned} Prob^{FI/CI}(s_i = 1) - Prob^{NI}(s_i = 1) = f(i)[&F(C - b_i(p(i) - p(i-1))) \\ &- f(i)F(C - b_i(g(i) - p(i-1)))], \end{aligned} \tag{A.7}$$

is decreasing in i if b_i is fixed for all agents i. □

[26]We maintain the requirement that agents cannot rationally believe that other agents are playing a dominated strategy, hence observing a contribution by the previous mover in CI implies that all previous movers contributed as well.

Appendix B: Experimental instructions

Welcome! Please end now all conversation with other participants, switch off your cell phone and read the following instructions carefully. If something is unclear, please raise your hand and we will come to you and answer your question individually.

The instructions are identical for all participants. During the experiment you remain anonymous. This means that none of the other participants will learn your identity. The experiment consists of two parts. In the first part you will have the opportunity to familiarize yourself with the software and the rules of the experiment. In the second part you interact in 12 repetitions (rounds) with other participants. You can earn money in each of these 12 rounds. How much money you earn will depend on your own and on the decisions of other participants. However, only one round will be paid out: at the end of the experiment the computer will decide at random which round will be relevant for the calculation of the earnings. The earnings of each participant of the experiment will then be calculated based upon the earnings in that round.

During the experiment all sums of money are listed in ECU (for Experimental Currency Unit). Your earnings during the experiment will be converted to Euro at the end and paid to you in cash. The exchange rate is 150 ECU = 1 Euro.

At the beginning of the experiment you and three other participants will be assigned to a group. The assignment is random and will remain fixed throughout the experiment. The members of a group work jointly, one after the other on a project. There are four roles in each group A, B, C and D. A works first, then B, C and last D. Each group member has to decide whether he or she works hard or normal on the project. The revenue of the project increases with the number of hard working group members. The income of each member depends on the revenue as well as the individual wage factor. The wage factor depends on the position in the production process: the factor increases for later movers.

We will now explain a round in detail. At the beginning of each round you will be assigned one of the four roles at random. The assignment is done at the beginning of each round via a random mechanism. Your role determines your position in the production process and thus also your wage factor. Then each member decides, one after the other, about his or her effort level, which can be hard or normal. As the graph shows, A decides first then B then C and at last D.

NI To decide on your effort level in a round, you have to wait until the roles before you have decided. You will learn at the end of the round, how the other members in your group have decided.

CI To decide on your effort level in a round, you will have to wait until the roles before you have decided. Before you make your effort decision, you will learn what your predecessor has decided. If you have for instance role C, you will learn whether B decided to work normal or hard. Equally your successor D will learn, before he or she decides, whether you C has worked hard or normal.

FI To decide on your effort level in a round, you will have to wait until all the roles before you have decided. Before you make your effort decision for this round, you will learn how many of your predecessors have decided to work hard. For instance, if you have role C, you will learn how many of your predecessors (A and B) have decided to work hard. Equally your successor D will learn, before he or she decides, how many of his predecessors (A, B and C) have decided to work hard.

The more members decide to work hard, the higher is the return of the project. The return is generated according to the following table:

IRS

Number of hard working members	0	1	2	3	4
individual return from project	180	190	220	310	500

LIN

Number of hard working members	0	1	2	3	4
individual return from project	180	260	340	420	500

IRS For instance if all members of the group decide to work normal, the return is 180. If you and exactly one other member decide to work hard the return will be 220 etc.

LIN For instance if all members of a group decide to work normal, the return per member is 180. If you and exactly one other member decide to work hard the return will be 260. etc.

Return and Costs For each unit produced, the members receive – contingent on their particular role – ECU. The return is distributed according to the following table.

Role	A	B	C	D
Factor	4	4	5	5

If you for instance have the role A in a particular round. Your wage factor in this round is 4. You will then receive with a return of 180 units 720 ECU. With a return of 500 units you will receive 2000 ECU etc.

Costs Working hard causes costs of 650 ECU. If you decide to work hard 650 ECU will be deducted from your return. If you decide to work normal nothing will be deducted.

IRS: For instance if you have the wage factor 5 in a particular round, and you and exactly one other group member decides to work hard the return from the project will be 220. You will then receive $220x5 = 1100ECU$, minus costs of 650 ECU for working hard, and your return in this round will be 450 ECU.

LIN: For instance if you have the wage factor 5 in a particular round, and you and exactly one other group member decides to work hard, the return of the project is 340. You will then receive $340x5 = 1360ECU$, minus costs of 650 for working hard, and your return in this round will be 450 ECU.

Procedure You will first have the opportunity to test the software for five minutes. Here you will be acting in all four roles simultaneously. Nothing that you will do in these five minutes will have any implication on your payoff. Also no other participant will be able to observe what you are doing. After the five minute test phase the second phase starts.

NI At the beginning you will learn which of the four roles you were assigned to in this round. Then, as explained above, the participants will decide one after the other whether to work hard or normal in this round (first A then B then C etc.) After you have taken your decision we will ask about your expectations. Please state how you think the other members have decided. At the end of the round you will be informed about the decision of the other members and your payoff in this round. In the next round the random mechanism will again assign you one of the four roles.

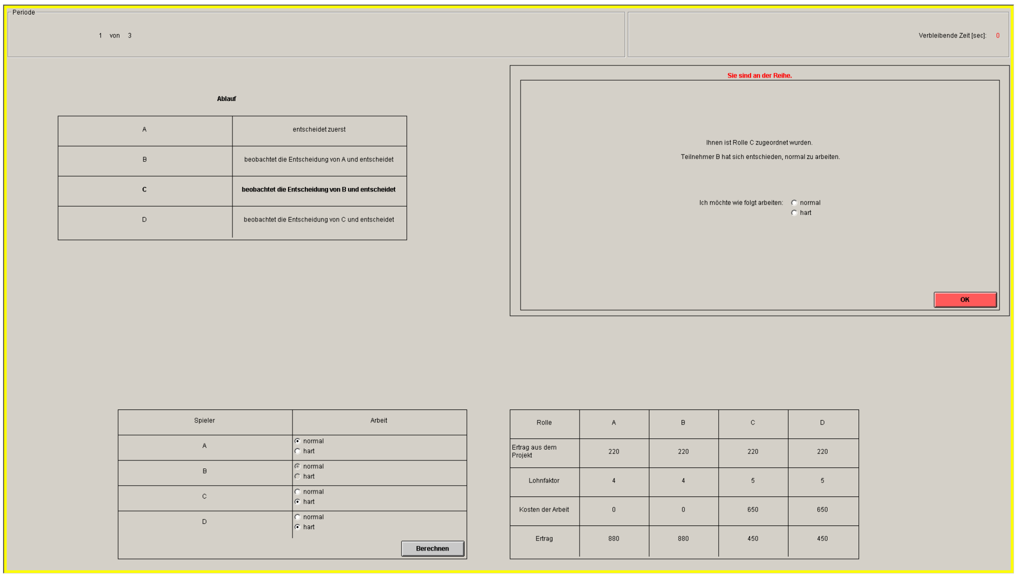
CI At the beginning you will learn which of the four roles you have in this round. Then, as explained above the participants will decide one after the other whether to work hard or normal in this round (first A then B then C etc.) Before you take your decision you will learn the decision of your predecessor. This means that B knows A's decision, C knows B's decision and D knows C's decision. After you have taken your decision we will ask about your expectations. Please state how you think the other members have decided. At the end of the round you will be informed about the decision of the other members and your payoff in this round. In the next round the random mechanism will again assign you one of the four roles.

FI: At the beginning you will learn which of the four roles you have in this round. Then, as explained above, the participants will decide one after the other whether to work hard or normal in this round (first A then B then C etc.) Before you take your decision you will learn the decision of all your predecessors. This means that B knows A's decision, C knows A's and B's decision and D is aware of A's, B's and C's decision. After you have taken your decision we will ask you – where appropriate – about your expectations. Please state how you think the other members have decided. At the end of the round you will be informed about the decision of the other members and your payoff in this round. In the next round the random mechanism will again assign you one of the four roles.

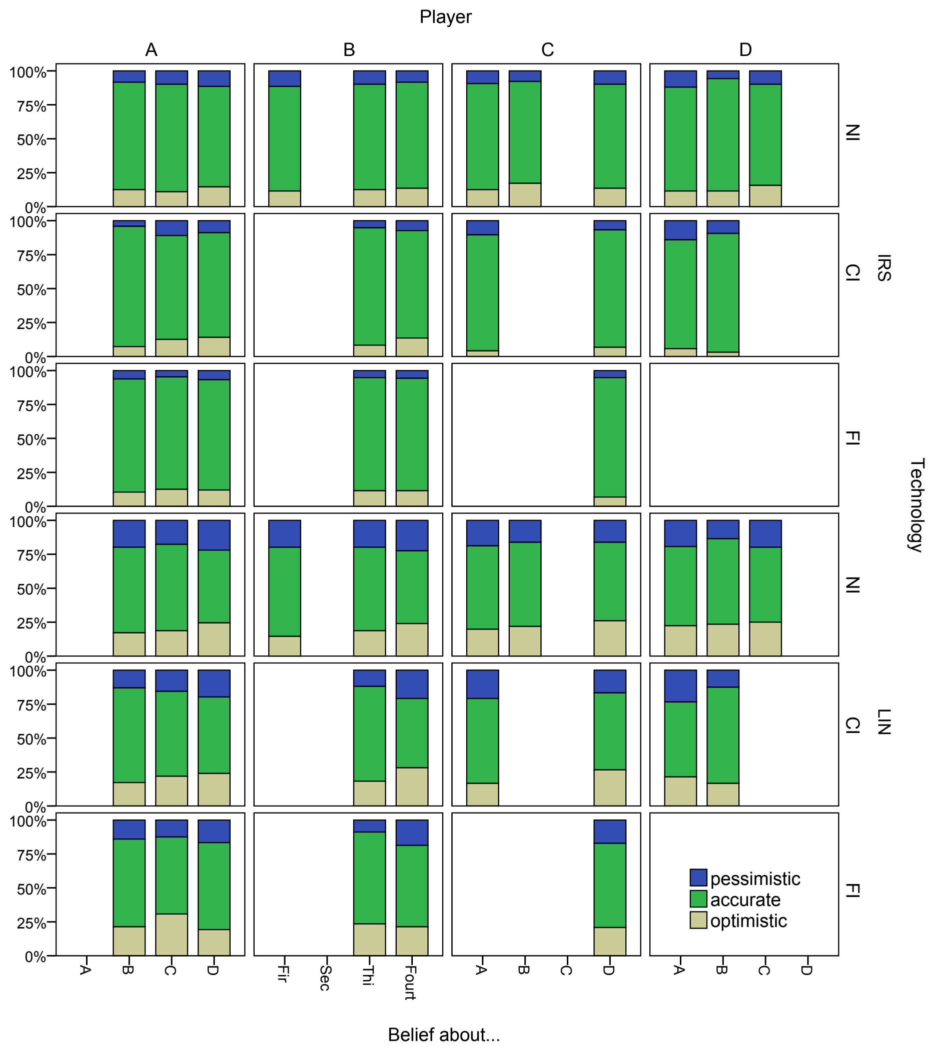
The end of the experiment

After you have completed the 12 rounds the experiment is over. One round will be selected at random for payment. For every participant his or her payoff is the return achieved in that round. Also for every participant one round will be selected at random for the expectations. However, this round will not be the same as the one chosen for payment. A correct expectation will be rewarded with 150 ECU. At the end we will ask you to fill out a questionnaire. Please remain seated until we call your cabin number. Thank you for participating in this experiment and have a nice day.

Appendix C: screenshot



Appendix D: beliefs accuracy



Note: a belief is categorized as optimistic (pessimistic) if a player guessed that the other player contributed (did not contribute), when in fact the opposite was true.