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Information Regime Changes and Path Dependence An Experimental Analysis of Public Goods Contributions in Heterogeneous Groups *

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Abstract/Résumé

We experimentally investigate the path dependence of voluntary contributions in a public good game with heterogeneous agents who vary in their ability to increase the public good. More specifically, we analyze whether contribution norms observed in a first phase of the experiment under a specific information regime carry over to a second phase with a more or a less transparent regime. We find evidence of path dependence that varies by the ability of agents. Efficient contribution norms establish under common knowledge about heterogeneity and transparency of contributors' ability, and they carry over to another game with less transparency. Other contribution norms that emerged under less transparency are also initially sticky, but they eventually evolve toward an efficient norm under a more transparent information regime. Thus, path dependence may impede but does not prevent efficient contribution norms to prevail in fully transparent settings.

Keywords/Mots-clés: Voluntary Contribution Mechanism, Heterogeneous MPCR, Information Transparency, Sticky Behavior, Behavioral Change, Social Norms

JEL Codes/Codes JEL: C92, D04, D63, D79, D89, D91, H41, H49

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1. Introduction

To build and enhance cooperation, information and transparency about others behavior can be a powerful means (see, for instance, Fiala and Suetens, 2017, for a meta-study). In recent years, particularly the idea of nudging people by information to foster pro-social behavior has gained momentum as a relatively cheap intervention (Bicchieri and Dimant, 2019). However, the literature also knows examples of nudges that are not successful or that even have undesired effects (e.g., Bolton et al., 2020; Dimant et al., 2020; Dur et al., 2019, for recent examples). A general difficulty is that behavior in a newly implemented choice architecture may be influenced by the original decision environment, delaying or even preventing behavioral change in decision environments with relatively sticky behavior (Kahan, 2019).

Unlike in the induced situations of a lab experiment, policies in the real-world can rarely start off with a clean slate. Decision makers typically have to decide in environments where a (common) previous history of social interaction sets a precedent. The stickiness of behavior may then dampen the behavioral effects of interventions in general. Especially, interventions that target beliefs or try to abrogate previous knowledge by providing information (or by making it salient) may prove less effective in case behavior is path dependent or sticky.

The implications of path dependent behavior have been theoretically (Bednar et al., 2015; Bednar and Page, 2018; Dolan and Galizzi, 2015) and empirically investigated in a number of studies, for instance in the area of tax compliance (Brttel and Friehe, 2014; Kamm et al., 2021), environmental behavior (Marchal, 2010; Levin et al., 2012; Lanzini and Thogersen, 2014), or risky choice (Hytnen et al., 2014; Kluger and Miele, 2020). The related concepts reported in experimental studies of multiple games include precedent transfer and behavioral spillovers. The first characterizes observations that efficient action in a precedent game increases the efficient action in a subsequently played, similar game (Knez, 1998). The latter refers to how behavior in a precedent game affects the outcomes of a subsequently played, strategically different game (Bednar et al., 2012; Cason et al., 2012).

Most of these experimental studies focus on the effects of previous experience and path dependent behavior by comparing different strategic environments, i.e., game types, group compositions, or incentives. The current study focuses on the path dependence of social norms in public good games with heterogeneous agents. More precisely, we investigate whether contribution norms that have established in heterogeneous groups under a specific information regime carry over – after a restart of the game – to behavior under a different information regime. In other words, we study whether social information is equally effective in promoting cooperation with previous experience than it is without.

This study ties in with a recent paper by the same authors (Fellner-Rhling et al., 2020) that investigates how information and contribution transparency affects voluntary contributions to a public good by heterogeneous group members. We found that full information about the existence of heterogeneity and transparency about contributions by different types leads to the most efficient outcome, i.e., a contribution norm where types with higher ability to increase the public good for others contribute more. In the present paper, we extend these insights by investigating the dynamics of cooperation by different types when the specific information regime changes. More specifically, two types of subjects, with either low or high ability, interact repeatedly in a public good game for 15 periods (the precedent game) under a specific information regime that offers no, partial or full information about the heterogeneity in the group and contributions by type. Afterward, a restart is announced and subjects interact for another 15 periods in the same groups (and with constant types) but under a different information regime that may become more or less transparent than in the precedent game.

The experimental evidence suggests that efficient contribution norms established under a regime of full information about heterogeneity and transparency of contributorss types indeed carry over and persist in a less transparent information regime. Other contribution norms that emerged in a regime with partial information are initially continued in a full information regime illustrating the path dependence of behavior. However, after repeated interaction, the full information regime unfolds the same efficiency-enhancing effect on contributions as without prior experience. We conclude that information about heterogeneity significantly enhances the contributions of all types in heterogeneous groups.

The remainder of the article is organized as follows. In Section 2, we present the experimental design and procedure. Section 3 starts with a descriptive overview of the data, then introduces the empirical model of individual contribution behavior and presents the estimation results. We conclude with a brief discussion in section 4.

2. The experiment

The main goal of our research is to study to what extent behavioral change in social norms is affected by path dependence. We study this question in a public goods framework with heterogeneous agents. More specifically, group members differ in the external return they generate for others by each unit contributed to the public good. As we show in our previous work (Fellner-Rhling et al., 2020), in such a setting, the social norms that evolve are affected by the available information about the heterogeneity in a group. However, this previous work looked at the relation between information and social norms in isolation. When designing real world policies to achieve behavioral change based on the insights from the experiment about which information structure works best, one has to face the challenge that a previous information structure might affect the outcome. The objective of the experiment that we present and analyze in the following is to study whether and to what extent social norms are robust to the initial information structure (i.e., the precedent) in a group. We therefore study contributions to a public good over two phases, where phase 1 sets the precedent for phase 2.

2.1. Heterogeneity in external returns and payoff function

In the experiment, subjects are randomly divided into groups of six members ($n = 6$). Groups stay constant throughout the course of the experiment. In every period, each group member receives an endowment ($w = 17$) that the member divides between a private account and a public good.[1] The part of the endowment allocated to

[1]All amounts in the experiment are given in points that are converted to € at an exchange rate of 80:1 at the end of the experiment.

the private account $(w - c_i)$ has a return of 1 per unit. Member i's contribution to the public good c_i generates an external return for other group members, and vice versa, each group member i benefits from the external returns generated by other group members' contributions. We denote by *external return* ϵ_j the factor by which one unit contributed by group member j increases the public good for others and by μ how much i benefits from the public good. We denote by *internal return* the return group member i receives from the public good for each unit i contributes. We implement two external return types: a low type with ϵ_L and a high type with ϵ_H, to whom we refer to as L-type and H-type hereafter. Within each group of six, there are three H-types (with $\epsilon_H = 3.99$) and three L-types (with $\epsilon_L = 1.33$). Each contribution generates an internal return of zero for all group members. Thus, the net costs for group member i for each unit contributed to the public good are equal to 1.

Finally, we denote by the *external individual return* $\mu\epsilon_j$ how much a group member i benefits from another group member's contribution. The valuation of the public good is the same for each member ($\mu = 1/4$) and everyone benefits from the effective contributions of four other group members (excluding themselves and another randomly selected group member of an opposite type). Thus, with external returns of $\epsilon_L = 1.33$ and $\epsilon_H = 3.99$, external individual returns for a nominal contribution of L-types and H-types are $\mu\epsilon_L = 0.3325$ and $\mu\epsilon_H = 0.9975$, respectively.

The payoff function of group member i is:

$$
\begin{aligned}
\pi_i \quad &= \quad w - c_i + \mu \sum_{\forall j \neq i,k}^{n} \epsilon_j c_j \\
&\quad \text{with } \epsilon \in \{\epsilon_H, \epsilon_L\}, H \in \{1, \ldots, n/2\}, L \in \{n/2+1, \ldots, n\}, \epsilon_i \neq \epsilon_k; i,k \in \{1, \ldots, n\}
\end{aligned}
$$

To put the payoff function into perspective, what we denote by *external individual return* is in the standard public good literature typically referred to as the *marginal per capita return* (hereafter $MPCR = \mu \cdot \epsilon_i$) which also equals the internal return.[2] As heterogeneity in the MPCR of group members typically creates heterogeneity in costs of contributing to the public good,[3] we split the MPCR into an internal and an external return to separate the costs of contributing and its benefits for others. The separation enables us to introduce variations in the ability to increase the public good for others (via the external return), while keeping the costs of contribution constant across types (via the internal return).

Furthermore, each group member i benefits from contributions of $n-2$ members ($\sum_{\forall j \neq i,k} \epsilon_j c_j$) excluding member i (because of the zero internal return) and another member k of the opposite type to i ($\epsilon_i \neq \epsilon_k$). We note that the internal return of zero for all members represents a boundary case of a public good where nobody benefits from their own contribution. The fact that group member i does not benefit from the contribution of

[2] For a comprehensive overview of different payoff functions used in the public goods literature and how they relate to each other see Fellner-Rhling et al. (2020).

[3] For example, a one-unit contribution by a person with high MPCR increases the public good by more than a one-unit contribution of a person with low MPCR as $MPCR_H > MPCR_L$. At the same time, the net costs of the same effective contribution to the public good is lower for a person with high MPCR compared to a person with low MPCR ($1 - MPCR_H < 1 - MPCR_L$). These two simultaneous effects of heterogeneity in MPCR render it difficult to identify whether persons with high MPCR contribute more because they increase the public good more effectively or because their costs are lower.

another member of the opposite type ensures symmetry of the payoff structure for all participants.[4]

2.2. Procedure, information regimes, and treatments

Participants were recruited using the online recruitment system ORSEE (Greiner, 2015). The experiment was conducted at the laboratory of the Max Planck Institute of Economics in Jena, Germany, and lasted on average 60 minutes. Participants received written instructions and took their decisions on the computer with the help of the software zTree (Fischbacher, 2007). Before the experiment started, all subjects had to pass control questions to ensure understanding of the interaction and incentives. The instructions informed subjects about the set up in phase 1, that there would be a phase 2, and that each of the phases would last 15 periods.[5] Subjects were also told that they would receive further instructions for phase 2 only after completing phase 1.

Each period followed the same procedure: all group members received their endowment and simultaneously chose their contribution to the public good. They were then informed about their payoffs and in addition, they saw a history table on the screen with a list of nominal contributions by each group member in all previous periods of the specific phase. However, contributions over time could not be attributed to a specific group member, as the order of contributions in the history table was randomized.

We employed three different information regimes, the *No-info*, the *Part-info* and the *Full-info* regime. In the *No-info* regime, subjects knew their own type, i.e., they were informed about their own external return, but they did not know that there were other external return types in their group.[6] In the *Part-info* and *Full-info* regimes, subjects learned the distribution of types in the instructions. Additionally, in the *Full-info* regime, the history table linked individual nominal contributions to the contributor's type. In sum, the three different regimes gradually vary the level of information about the heterogeneity in external returns within the group and the transparency in whether the contributor's type can be identified in the feedback.[7] Table 1 presents the structure of the three information regimes.

In phase 1, subjects participated in the three information regimes in a between-subjects design. Upon completion of phase 1, subjects learned that they would interact for 15 more periods within the same group and

[4] If we kept the internal returns (and thus the costs of contributing) constant across types and at the same time allowed each member to benefit from the contributions of all other group members, an asymmetric payoff structure would ensue. This is due to the fact that each member would benefit from contributions of fewer members of the own type and more members of the other type. Imagine that all members contributed the same nominal amount. This would result in H-types receiving a lower payoff from the public good because they benefited from contributions by fewer H-types, and in L-types receiving a higher payoff because they benefited from the external returns generated by the contribution of one more H-type. As an example, consider a group of six members with three L-types and three H-types. When the internal return is the same across types, all members would benefit equally from their own contribution. However, H-types would additionally benefit from contributions of three L-types and only two H-types, in contrast to L-types who would benefit from contributions of two L-types and three H-types. As each nominal unit contributed by a H-type members increases the public good by more than the same unit contributed by a L-type, the latter would receive a larger return from the public good.

[5] Appendix A presents an English translation of the original German instructions for phase 1.

[6] The instructions avoided the words "ability" or "external return" and was vague about the possibility that different external returns within the group might exist. While this approach implies a certain loss of control over group members' beliefs concerning heterogeneity, it implements the *No-info* regime as a benchmark as closely as possible to the other two regimes.

[7] Participants in all information regimes knew that they benefit from contributions of "four other group members" (*No-Info* regime) and "two of each type" (*Part-Info* and *Full-Info* regime), but they were not able to identify from which nominal contributions in the history table they benefited. It was therefore hardly possible to infer the type of the contributor from the nominal contributions in the history table in the *Part-Info* regime. Likewise, subjects in the *No-Info* regime could not easily infer that different types existed within their group.

Table 1: Summary of information regimes

	Information regimes		
	No-info	*Part-info*	*Full-info*
Information on external return types	own type	own type and distribution of external return types in group (common knowledge about heterogeneity)	
Transparency of contributors' types	*without* identification of contributors' types		*with* identification of contributors' types

that their external return type would stay the same. The instructions for phase 2 explained that the procedure to determine the public good remained the same as in phase 1, but highlighted the particular changes (if any) in the information regime.

The information regime changed for those groups with common knowledge about the heterogeneity in phase 1: groups that had experienced the *Part-info* regime in phase 1 participated in the *Full-info* regime in phase 2. Vice versa, groups that had experienced the *Full-info* regime in phase 1 participated in the *Part-info* regime in phase 2. Groups that had participated in the *No-info* regime in phase 1 experienced no information regime change in phase 2. The *No-info* regime serves as a control to asses the difference in contributions between settings with different levels of information about heterogeneity in contrast to the case without information. Further, this regime allows us to control for the commonly observed decay of public good contributions over time.

Three treatments result from the (possible) information regime change: *No-info* followed by *No-info*, *Part-info* followed by *Full-info*, and *Full-info* followed by *Part-info*. In the *No-info/No-info* treatment, subjects were informed that the same public good game would continue for another 15 periods without any changes. In the *Part-info/Full-info* treatment, subjects were informed that the history table of contributions in phase 2 would additionally identify the type of the contributor. In the *Full-info/Part-info* treatment, subjects learned that while they would still receive a history table indicating individual contributions of all group members in phase 2, it would not display the type of the contributor. In each of the three treatments, 54 subjects participated in 9 groups, 27 subjects of each L- and H-type.

The first period of phase 2 (period 16) started as soon as all participants had indicated that they had read and understood the instructions for phase 2. At the end of the experiment, subjects filled in a post-experimental questionnaire, including standard background characteristics, such as age and gender, and a personality questionnaire. The latter allows to attribute a personality index to each subject that we use as a control for the

Table 2: Summary of experiment: within-subjects treatments and descriptive statistics

	Phase 1	**Phase 2**
Periods	1–15	16–30
Subjects/treatment	54	54
Groups/treatment	9	9
Contribution decisions/treatment	810	810
Contribution decisions total	2,430	2,430
Treatments	**Contribution rates (std. dev.)**	
No-info/No-info	***No-info***	***No-info***
Mean (SD)	0.43 (0.26)	0.34 (0.22)
L-type	0.42 (0.22)	0.34 (0.17)
H-type	0.43 (0.29)	0.33 (0.27)
Part-info/Full-info	***Part-info***	***Full-info***
Mean (SD)	0.55 (0.28)	0.45 (0.28)
L-type	0.59 (0.29)	0.48 (0.29)
H-type	0.50 (0.27)	0.42 (0.28)
Full-info/Part-info	***Full-info***	***Part-info***
Mean (SD)	0.55 (0.29)	0.51 (0.29)
L-type	0.50 (0.29)	0.48 (0.30)
H-type	0.62 (0.28)	0.55 (0.28)

Note: Contribution rates are nominal contributions as a share of the endowment.

idiosyncratic relevance of social norms.[8] The higher the index, the higher is the awareness of and the personal reliance on social norms and rules. Subjects then received their earnings and a show-up fee of €2.5 in cash. Earnings amounted to 908 points, on average, corresponding to €11.3 (by treatment: *No-Info/No-info*: 834 =€10.4, *Part-info/Full-info*: 907 =€11.3, *Full-info/Part-Info*: 982 =€12.3) for both phases.

3. Results

3.1. Descriptive Statistics

In total, 162 undergraduate students from the University of Jena took part in the experiment. Subjects were on average 24 years old and 43% (70) of them were men. The personality index capturing the personal reliance on norms, with higher values indicating stronger personal relevance of norms, lies between 1 and 9 with an average value of 4.35. We observe a total of 4,860 contribution decisions (3 treatments x 2 phases x 15 periods x 9 groups x 6 members per group). We express the main variable of interest, the contribution rate, by normalizing the nominal contribution as a share of the endowment to range from 0 to 1.[9]

The bottom part of Table 2 displays the mean of average individual contribution rates for each information

[8] More specifically, we administered the revised version of the Sixteen Personality Factor Questionnaire (Cattell et al., 1993) in its official German version by Schneewind and Graf (1998). The specific personality index we use is derived from the individual score in the global personality scale that captures conscientiousness. This index summarizes several individual traits associated with rule reliance and the importance to obey socially accepted behavior (Conn and Rieke, 1994). The index results in sten values that can range from one to ten and are derived by comparing test scores to a norm population. The average (expected) sten value in the German population is 5.5 with a standard deviation of 2.

[9] In the following, we use the term 'contribution' synonymously to contribution rate for ease of presentation.

regime in each phase. Comparable to the general evidence on voluntary contributions, participants contribute, on average, about 40% to 60% of their endowment in phase 1, and lower their contributions to about 33% to 55% in phase 2 after a change in the information regime (in two of the three treatments). In both phases, contributions in the *Part-info* and *Full-info* regime appear to be higher than under *No-info*.

The dynamics of contributions over time are shown in Figure 1. The figure plots the average contribution rate by treatment across the 30 periods of both phases, aggregated over both external return types. In all information regimes of both phases, the average contribution generally decreases over periods, with a stronger decay toward the end.

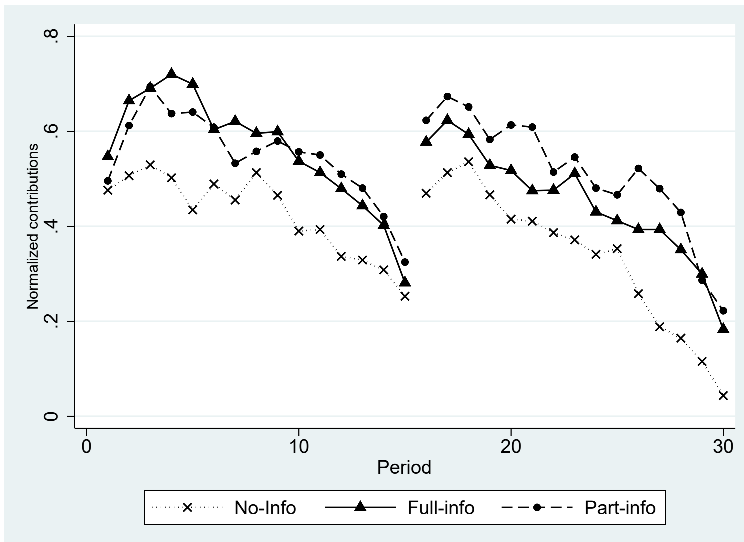

Figure 1: Average contribution rates over time in all three treatments, aggregated over external return types

Note: Groups that were in the *No-info* (*Part-info*) [*Full-info*] regime in phase 1 (periods 1 to 15) continued with the *No-info* (*Full-info*) [*Part-info*] regime in phase 2 (periods 16 to 30).

In phase 1 of the experiment (the precedent game), some differences across information regimes in how contributions evolve over time stand out. In the *No-info* regime, the general trend of contributions is downward sloping, a behavior that mirrors the general evidence of other public goods experiments. In contrast, in both regimes with common knowledge about heterogeneity (*Part-info* and *Full-info*), the average contributions seem to first increase before declining in the typical manner.

At the beginning of phase 2, we observe a restart effect in all treatments which is a common pattern in public goods games. With a constant information regime (treatment *No-info/No-info*), phase 1 looks fairly similar to phase 2 with the exception of a stronger decay of contributions in the second half of periods. The two regimes with common knowledge about heterogeneity (*Part-info* and *Full-info*) again seem to induce higher contributions than the *No-info* regime.

In the following, we exploit the individual level data by estimating an empirical model of contribution behavior to investigate whether the social norms that evolve in heterogeneous groups are affected by path dependence.

3.2. Empirical model of contribution behavior

In order to capture the dynamic effects of the information regime change, we estimate a random effects Tobit model.[10] This allows to quantify the effects of information and external returns on contribution behavior before and after the regime change while at the same time controlling for individual heterogeneity.

At the extremes, group members could contribute from nothing at all up to their whole endowment making individual contributions potentially double-censored.[11] Our estimation approach therefore employs a standard regression doubly censored Tobit model. We estimate the relation for the latent proportion $y_{it}^{\star}$ that a group member i contributes to the public good as[12]

$$y_{it} \begin{cases} = 0 & \text{if } y_{it}^{\star} \leq 0, \\ = y_{it}^{\star} & \text{if } 0 < y_{it}^{\star} < 1, \\ = 1 & \text{if } y_{it}^{\star} \geq 1. \end{cases} \tag{1}$$

We model the share that individual i contributes from his or her own endowment in period t by $y_{it}^{\star}$:

$$y_{it}^{\star} = \beta + \mathbf{Info}_i\gamma + \mathbf{h}_i\omega + f(t) + phase \cdot \delta + \mathbf{x}_i\beta + u_{it} \tag{2}$$

with β representing the low type's base level contribution in the *No-info* treatment before the regime change. The vector $\mathbf{Info}_i$ contains two dummy variables, one for each the *Part-info* and the *Full-info* regime. The parameter estimates in the γ vector capture basic differences between information regimes. The vector $\mathbf{h_i}$ contains a dummy variable for the external return type ($High_i = 1$ if i is a H-type and zero otherwise) and interaction terms of the type with the information regime, allowing types to behave differently depending on the regime. The parameter vector ω measures the effect of types across information regimes. We control for time trends within a regime by including $f(t)$, a quadratic polynomial that includes interaction effects with types and the three information regimes.[13] We also control for the regime change itself by including an indicator variable 'phase' that is equal to one for periods 16 to 30. In addition, vectors $\mathbf{Info}_i, \mathbf{h}_i$, and $f(t)$ contain interaction terms with the variable 'phase' allowing these variables to affect contributions differently before and after the regime change. The vector $\mathbf{x}_i$ represents individual observable characteristics (age, gender, personality index). Their influence on contributions is captured by the parameter vector β. Idiosyncratic errors, u_{it}, are assumed to be independent of the type and other individual characteristics in $\mathbf{x}_i$.

[10] This analysis follows in part our previous work on studying the effect of heterogeneity in external returns on contributions in public goods games (Fellner-Rhling et al., 2020).

[11] We indeed observe 25% of all contributions at the lowest contribution rate of 0% and 21% at the highest rate of 100% of the endowment.

[12] We thank Charles Bellemare for providing his Tobit model OX code.

[13] We first estimated a model including a non-parametric time trend, i.e., indicator variables for each of the 15 periods per phase. Estimation results from this model revealed an inverse-U relation between time and the contribution to the public good. Parameterizing the time as quadratic polynomial allows us to account for both linear and nonlinear effects of the found time trend as well as include interactions with the different information regimes while minimizing the loss of degrees of freedom.

$$f(t) = \tau_{10} \cdot t + \tau_{20} \cdot t^2 + Interaction(t, High_i, Part\text{-}info_i, Full\text{-}info_i, phase).$$

3.3. Parameter estimates and marginal effects

Table 3 presents the parameter estimates of two specifications. In Specification (1), all variables – the main treatment variables, i.e., information regime, phase, type, as well as background characteristics and time dummies – enter only once and linearly as regressors. The results indicate that contributions are significantly higher in both the *Part-* and *Full-info* regimes compared to *No-info* ($\gamma_1, \gamma_2 > 0$). Thus, informing members of a group about the heterogeneity in the ability to increase the public good has a positive impact on contributions. The effect of information seems fairly similar for both *Part-info* and *Full-info* regimes. Further, we observe that, on average, H-types contribute more. Background characteristics are correlated with contribution behavior. More precisely, we find that women contribute on average less ($\beta_2 < 0$) than men. Age and the personality index have significant but relatively small negative effects on contributions. All effects are significant at $p = 2.5\%$ or less. The period (dummy) coefficients (presented in Table C.4 in Appendix C) show that contributions evolve over time in a nonlinear, hump-shaped way.

Specification (2) implements the model of equation (2) including the interaction effects of the information regime variables. The time trend is modeled parametrically as a quadratic polynomial to best approximate the time trend found non-parametrically in Specification (1). Parameterizing the time trend allows us to add interaction effects with time while minimizing the loss in degrees of freedom. Specification (2) estimates the observed contribution behavior in more detail allowing the contributions of the two types to differ by information regime, phase, and time. Parameter estimates of the constant and the background characteristics are almost identical in both specifications. To what extent the other co-variates significantly affect contribution behavior is difficult to assess from looking at the parameter estimates because they enter via different interaction terms.

For the purpose of testing the joint effect of the parameter estimates from Specification (2) and to appreciate the global picture of these individual interactions, Figure 2 presents the predicted contributions as well as marginal effects and their 95% confidence bounds based on estimated parameters of Specification (2) for the three treatments over time and by phase (phase 1: periods 1 to 15, and phase 2: periods 16 to 30), separately for H-types (solid lines) and L-types (dashed lines).[14,15] We observe some similarities but also important differences in contribution patterns between information regimes and treatments. There is no difference in nominal contributions of types in the *No-info/No-info* treatment (top panel in the left column), indicating that efficient contributions, i.e., higher contributions by types with a higher ability to increase the public good, do not arise as an intrinsic reaction to the benefits of contribution. It seems that a norm of equal nominal contributions establishes in this treatment. Rather different norms seem to emerge when heterogeneity is common knowledge. In the *Part-info/Full-info* treatment (middle panel in the left column), L-types contribute more in phase 1 as well as in the beginning of phase 2, whereas H-types contribute significantly less during most of both phases with a little change in relative contributions between both types only at the end of phase 2. There, H-types contribute more than L-types, even though the difference is not significant. In the *Full-info/Part-info* treatment

[14] Figure B.3 in Appendix B shows the observed and predicted type-specific contributions for all treatments and periods side by side and visually highlights the fit of the predictions to observed data.

[15] Appendix D explains the details on the computation of the marginal effects.

(bottom panel in the left column), H-types contribute more than L-types in phase 1 and most of the periods in phase 2. Finally, without exception, in all information regimes contributions of both types decrease over time.

In order to better comprehend the effect of common knowledge about heterogeneity and the transparency of contributors' types on contributions to the public good by both types, we compare contributions of types across treatments. The three panels in the right column of Figure 2 show the marginal effect of a particular regime on type-specific contributions, which is the difference in the average estimated contribution rate over time between the *Full-info* and *Part-info* regimes (top), the *Part-info* and *No-info* regimes (middle), and the *Full-info* and *No-info* regimes (bottom) in both phases.[16]

Comparing behavior across information regimes in phase 1 in these graphs allows to investigate the effect of information on contributions without prior experience, which is the principal question in Fellner-Rhling et al. (2020). For example, the solid line in the top panel in the right column shows the difference in H-types' average contributions between the *Full-info* and the *Part-info* regime for each period. In the *Full-info* regime, H-types contribute on average 18% more than in the *Part-info* regime in the first period, increasing to 20% around period 5 and decreasing toward the end of phase 1. These differences are significantly different from zero as indicated by the narrow confidence bounds that exclude the zero line. L-types contribute on average less in the *Full-info* regime than in the *Part-info* regime in phase 1.

Moreover, the comparison of these two regimes with the *No-info* regime in the middle and bottom panels of the right column allows to understand the effect of common knowledge about heterogeneity in relation to no information about the heterogeneity in the group. We observe that both types contribute significantly more in both information regimes with common knowledge about the heterogeneity compared to the *No-info* regime. Because there are no significant differences in the contributions between types in the *No-info* regime (see top panel in the left column), the graphs in the middle and bottom panel in the right column can also be interpreted as indicating the differences between types in the *Part-info* and, respectively, in the *Full-info* regime. In the *Part-info* regime of phase 1, L-types contribute more than H-types. This contribution pattern stands in contrast to the *Full-info* regime of phase 1, where H-types contribute more than L-types. Further, contributions of L-types in both the *Part-info* and *Full-info* regimes decline over time to the same level as contributions of L-types in the *No-info* regime. The contribution differences of H-types between the *Full-info* and the *No-info* regime remain relatively stable, whereas they increase over time between the *Part-info* and the *No-info* regime.

From these observations, we conclude in Fellner-Rhling et al. (2020) that common knowledge about heterogeneity in a group enhances contributions of all group members compared to a situation without knowledge about the heterogeneity. However, contribution patterns vary by the level of information. Simply being aware of the heterogeneity increases contributions of L-types, whereas H-types contribute more when, additionally, contributions can be linked to the type of the contributor. These results highlight the importance of choosing

[16]Recall from our experimental design in section 2 that subjects who participated in the *Part-info* (*Full-info*) regime in phase 1, experienced an information regime change to *Full-info* (*Part-info*) in phase 2. Only the groups in *No-info* participated in the same information regime in both phases.
The treatment *No-info/No-info* without an information regime change serves as a control to map the time trend of contributions across periods and phases.

the right level of information in team work and joints projects. Depending on the composition of the group, it is preferable to emphasize that there are differences in group members' abilities (as in the *Part-info* regime) or to disclose heterogeneity completely including a performance measure of different group members (as in the *Full-info* regime) in order to stimulate contributions of a particular type.

In the following, we turn to the question to what extent these contribution patterns are affected by experience in a previous information structure. More precisely, we look at the differences in type-specific contribution behavior across regimes in phase 2 compared to phase 1. In phase 2, participants continued to interact in the same group for another 15 periods. Groups that had experienced the *Part-info* regime in phase 1, participated in the *Full-info* regime in phase 2. Vice versa, groups that had experienced the *Full-info* regime in phase 1, participated in the *Part-info* regime in phase 2. If the information effects on contributions in phase 1 are robust even in the presence of previous experience, we expect the same type-specific contribution pattern to replicate in phase 2.

In fact, we do not observe the same patterns emerging in phase 2. As shown in the top panel of the right column of Figure 2, the difference of H-type contributions between the *Full-info* and the *Part-info* regime becomes negative and significantly different from zero in phase 2. The difference of L-type contributions between the *Full-info* and *Part-info* regime also changes between phases, even though in the opposite direction. In phase 2, no significant differences in L-type contributions exist between these two information regimes. Thus, the type-specific contribution patterns in the same information regime change across phases in a systematic way. This suggests path dependence that is type-specific.

To better understand the change in patterns, we look at the marginal effects of the two levels of information presented in the middle and bottom panels in the right column of Figure 2, i.e., we compute the differences in type-specific contributions between regimes with common knowledge about heterogeneity and the *No-info* regime. When we compare these marginal effects of information on type-specific contribution behavior across phases, we observe some similarities between phase 1 and phase 2, but also important differences. As for similarities, we find that for both types contributions in phase 2 are larger in the *Part-info* and *Full-info* regimes than in the *No-info* regime, just like in phase 1.

There are also striking differences. The most noticeable change in contribution patterns occurs in the *Part-info* regime, where H-types (with previous experience in the *Full-info* regime) continue to contribute significantly more compared to H-types in the *No-info* regime but also compared to L-types in the *Part-info* regime. This pattern by type is inverse to the *Part-info* regime in phase 1. It seems as if differential patterns in behavior carry over from phase 1 to phase 2. We observe similar path dependence in behavioral patterns for subjects in the *Full-info* regime (with previous experience in the *Part-info* regime). There, L-types continue to contribute relatively more than H-types, just like in the previous information regime. However, being able to identify the type of the individual contributor seems to induce a transition toward a type-specific contribution pattern that resembles the one observed in the *Full-info* regime in phase 1: in the last two periods of phase 2, the difference of H-type contributions between *Full-info* and *No-info* regime is significantly larger than the corresponding difference of L-type contributions.

Thus, in both regimes with common knowledge about heterogeneity in external returns, an efficient contribution norm prevails, i.e., H-types contribute more than L-types. However, path dependence hampers this achievement when a different norm has been established before as in the case of the *Part-info* regime of phase 1. One explanation of our observations of contribution patterns by type over the two phases is that the information structure in the *Full-info* regime facilitates that the different types coordinate on an efficient contribution norm that implies larger contributions by types with a higher ability to increase the public good.

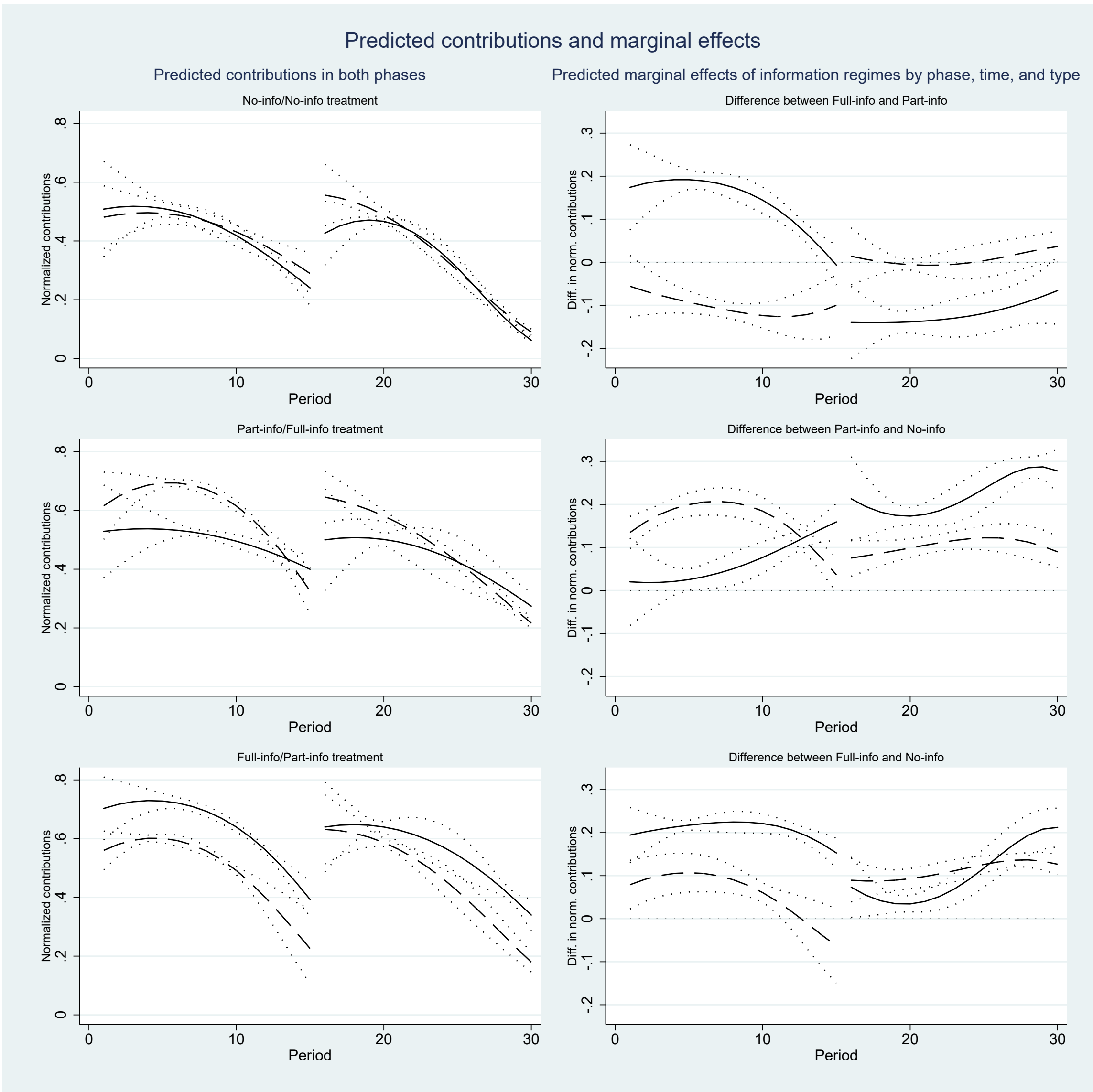

Figure 2: Left column: Predicted average contributions for the three treatments over time separately for H-types (solid lines) and L-types (dashed lines) with 95% confidence bounds.
Right column: Predicted differences between contribution rates of the *Part-info* and *Full-info* regime (top graph), as well as predicted differences between *Part-info* regime (middle graph) and resp. the *Full-info* regime (bottom graph) to *No-info* by phase, time, and type (dashed lines: L-types, solid lines: H-types) with 95% confidence bounds.

Table 3: Estimation results for contribution rates (dependent variable: nominal contribution as a share of the endowment).

		Specification (1)			Specification (2)		
Variable	Parameter	Coefficient	StD	T-value	Coefficient	StD	T-value
Constant	γ_0	0.792	0.060	13.304	0.793	0.136	6.283
Part-info	γ_1	0.260	0.012	21.488	0.131	0.168	0.830
Full-info	γ_2	0.229	0.011	20.182	0.115	0.133	0.860
H-type	ω_0	0.040	0.006	7.085	0.020	0.213	0.108
H-type *Part-info*	ω_1				-0.028	0.304	-0.091
H-type *Full-info*	ω_2				0.233	0.251	0.929
Phase H-type	ω_3				-0.332	0.258	-1.285
Phase H-type *Part-info*	ω_4				0.324	0.361	0.898
Phase H-type *Full-info*	ω_5				-0.118	0.353	-0.334
Phase	δ	-0.143	0.019	-7.543	0.155	0.134	1.157
linear term of the Time trend	τ_{100}				0.023	0.041	0.568
Part-info	τ_{101}				0.055	0.052	1.063
Full-info	τ_{102}				0.031	0.046	0.659
H-type	τ_{103}				-0.001	0.068	-0.015
H-type *Part-info*	τ_{104}				-0.063	0.094	-0.665
H-type *Full-info*	τ_{105}				-0.010	0.080	-0.125
Phase	τ_{106}				-0.028	0.051	-0.530
Phase Part-info	τ_{107}				-0.067	0.036	-1.304
Phase Full-info	τ_{108}				-0.039	0.037	-1.048
Phase H-type	τ_{109}				0.070	0.089	0.788
Phase H-type *Part-info*	τ_{110}				0.011	0.116	0.094
Phase H-type *Full-info*	τ_{111}				-0.029	0.117	-0.250
quadratic term of the Time trend	τ_{200}				-0.003	0.003	-1.174
Part-info	τ_{201}				-0.004	0.003	-1.291
Full-info	τ_{202}				-0.003	0.003	-0.989
H-type	τ_{203}				-0.001	0.004	-0.144
H-type *Part-info*	τ_{204}				0.006	0.006	1.014
H-type *Full-info*	τ_{205}				0.002	0.005	0.316
Phase	τ_{206}				-0.001	0.003	-0.355
Phase Part-info	τ_{207}				0.004	0.003	1.414
Phase Full-info	τ_{208}				0.005	0.003	1.429
Phase H-type	τ_{209}				-0.003	0.006	-0.589
Phase H-type *Part-info*	τ_{210}				-0.002	0.007	-0.214
Phase H-type *Full-info*	τ_{211}				0.002	0.007	0.288
Age	β_1	-0.006	0.001	-6.699	-0.006	0.001	-6.566
Female	β_2	-0.191	0.006	-31.474	-0.185	0.007	-27.874
Personality index	β_3	-0.023	0.002	-14.289	-0.023	0.002	-13.935
Time dummies		Yes			No		
	σ_ϵ	0.599			0.594		
Number of Observations		4860			4860		
Number of Parameters		22			37		
Log-Likelihood value		-133901			-132391		

4. Conclusion

In this paper, we investigate whether the efficiency-enhancing effect of information in public good games with heterogeneous agents is robust in light of previous experience. In our experiment, group members vary in their ability to increase the public good with their contributions. We study a case with two levels of ability, low and high, and vary the level of information group members have about the heterogeneity in the group and whether or not the type of a contributor can be identified. In such a setting, different social (contribution) norms can emerge: either a norm of equal nominal contributions by both types, a norm of equal effective contributions, or an efficient contribution norm. We are particularly interested in whether contribution norms that establish under a specific information regime (in a precedent game) persist after switching to a regime with higher or lower transparency.

First, we find different norms to emerge initially depending on the information provided. When group members have no information about the heterogeneity, the prevailing norm is equal nominal contributions by type. With common knowledge about heterogeneity, contributions are higher in general, but type-specific behavior is largely driven by the transparency of the information regime: only in case contributions can be linked to the type of the contributor, an efficient contribution norm establishes, where high ability types contribute more than low ability types.

Second, we find that contribution norms are sticky at first. In fact, when the information regime changes from knowing the contributor's type to not knowing and vice versa, types continue their prior contribution pattern. In case the efficient contribution norm has established in the precedent information regime (with transparency about contributors' types), the path dependence of behavior results in a continuation of behavior abiding this norm even without transparency. In case a different contribution norm has established (without transparency about the contributors' types), the change to an information regime with transparency upends the stickiness of behavior, but only after some time, so that eventually, the efficient contribution norm takes hold.

One potential explanation of the effects we find is that it is easier to coordinate on information that is available. Without information, the only 'communication' that group members have is via the individual contributions of other group members displayed at the end of the interaction. Thus, a norm of equal nominal contributions is likely to emerge. The most likely contribution norm to emerge is less obvious for the case where heterogeneity is common knowledge but contributors' types cannot be identified. It is much easier to coordinate in a regime that additionally reveals the type of the contributor. In this latter case, efficient contribution behavior emerges probably because coordination is easier to achieve.

Our results unambiguously show that information about heterogeneity significantly enhances the contributions of both types. We find that efficient contribution norms emerge and persist in heterogeneous groups after having had the opportunity to coordinate, even in the extreme case of public goods that we study, where the internal return from own contributions is zero.

This paper highlights the importance for choice architecture to consider the initial conditions before implementing new environments. Potential path-dependence might carry behavior from the old to the new choice environment and affect the outcome in unexpected ways. Inducing behavior change must therefore consider the stickiness of established social norms as it may dampen the success of interventions that modify the decision architecture.

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Appendices

Appendix A. Instructions

This is a translated version of the German instructions used for the experiment. We provide here the version for H-types in the No-info regime in phase 1. Differences between information-regimes are denoted as comments in the text. Comments by the authors included here as information to the reader but not in the original instructions can be found in square brackets and footnotes.

Welcome to this experiment! These instructions are for your private information. Please read the instruction carefully. Please do not talk to the other participants. If you have any questions, please raise your hand. We will come to you and answer your questions privately.
All amounts are displayed in *Points*. The exchange rate is: 80 points = 1 euro.
The experiment consists of two phases of 15 periods each. Before each phase, all participants are randomly assigned to groups of six. The group's composition remains the same throughout the experiment.

Detailed Information
You are a member of a group of six. At the beginning of each period, every group member receives 17 points. In every period each group member decides how to split the 17 points. You can transfer points to a private account or to a group project. Your period payoff is the sum of your income from the private account and the income from the group project.

<u>Your payoff from the private account:</u>
For each point you transfer to the private account, you receive a payoff of one point. This means that if you transfer an amount of x points to your private account, your payoff increases by x points. Nobody except you benefits from your private account.
<u>Your payoff from the group project:</u>
The payoff you receive from the project is derived as follows. You receive one quarter of the project's outcome generated by four other members of your group. The project's outcome is the sum of all transfers, whereby each transfer to the project is multiplied by an individual factor[, either 1.33 or 3.99. Two of the four members of your group whose transfers will benefit you have a factor of 1.33, and the other two have a factor of 3.99. Individual factors were randomly assigned to each group member in the beginning of the experiment such that three members were assigned a factor of 1.33 and three were assigned a factor of 3.99. Each member retains the same factor throughout the whole experiment.][17] The payoffs are calculated in the same manner for all six group members.
Each point you transfer to the group project generates 3.99 points.[18]
Please note that four other members of your group benefit from your transfer to the project, but you do not.

<u>One period proceeds as follows:</u>
In each period, you receive 17 points. You decide how many of your 17 points to transfer to your private account and how many to the project. You will make this decision by simply deciding how many points you wish to transfer to the project. The points you transfer to your private account are automatically calculated as the difference of the 17 points and the points you transferred to the project. After every group member has made a decision, the payoff for this period is calculated.
At the end of each period, you will receive the following information:

- The number of points that each member in your group transferred to the project (Please note that the numbers of points are listed in random order, i.e. the sequence of transfers is different in each period.)
- Your payoff from the private account
- Your payoff from the project

[17]The information between square brackets was **not given** in the *No-info* regime but was **given** in the *Part-info* and *Full-info* regimes.
[18]This was the factor for *H*-types. *L*-types had a factor of 1.33.

- Your payoff from the period
- Your total payoff from all previous periods in this phase

Then, the next period will start. In the second period, you will be shown a table (like the one below) with the following information for all previous periods: your transfer to the group project, your payoff in a period, and transfers made by the other 5 members of your group [with the information about their individual factors (H for 3.99 and L for 1.33)].[19] For each period, the transfers of group members are presented in random order, so columns showing the contributions of the other 5 group members will not correspond to the same person for all periods.

	Transfer to the joint project						
	You	Other group members					
		[H]	[H]	[L]	[L]	[L]	
Period		1	2	3	4	5	Payoff
1	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

In total, you will interact over 15 periods in each phase. You will receive more detailed information on phase 2 after phase 1 ends.
We will ask you to complete a questionnaire after the experiment is completed. At the end of the experiment, your final payoff will be converted into euro and paid to you immediately. Please remain seated until we call the number of your computer.

Thank you very much for your participation!

[19] Only participants in the *Full-info* regime received the information allowing them to link a contribution to the contributor's type.

Appendix B. Observed and predicted contribution rates

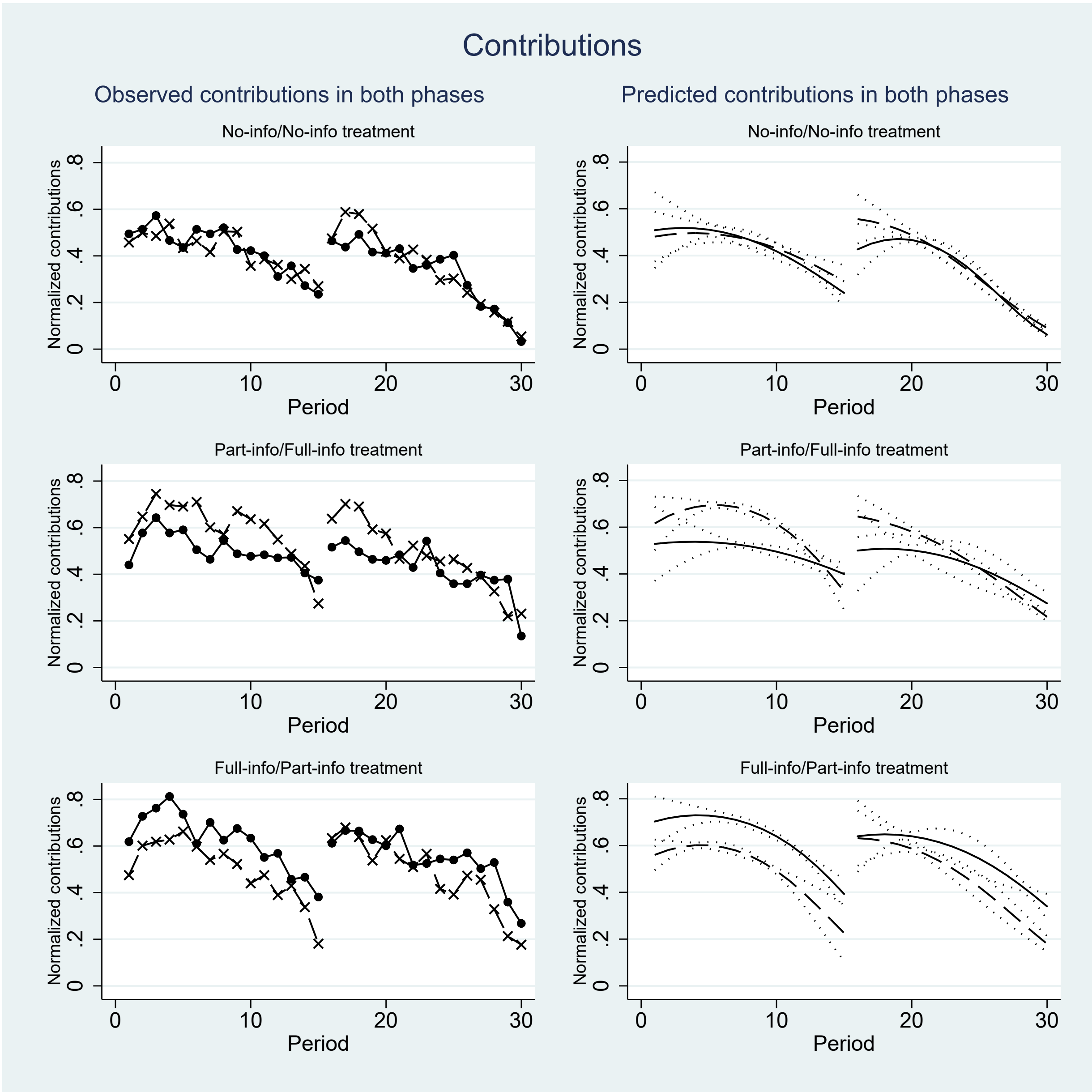

Figure B.3: Observed and predicted contribution rates for all treatments, separately for *L-types* (dashed lines) and *H-types* (solid lines)

Appendix C. Estimation results of period dummies

	Coefficient	StD	T-value
period 2	0.12243	0.11151	1.0980
period 3	0.13931	0.09990	1.3943
period 4	0.07324	0.09280	0.7892
period 5	0.03517	0.07936	0.4432
period 6	-0.00157	0.07661	-0.0205
period 7	-0.06228	0.07907	-0.7877
period 8	-0.03344	0.08453	-0.3956
period 9	-0.08175	0.08672	-0.9428
period 10	-0.13625	0.07415	-1.8375
period 11	-0.16292	0.08445	-1.9292
period 12	-0.23140	0.07919	-2.9223
period 13	-0.28593	0.07974	-3.5857
period 14	-0.41557	0.07752	-5.3609
period 15	-0.60761	0.07803	-7.7869

Table C.4: Time dummy estimates from specification (1) in Table 3.

Appendix D. Marginal effects of information and external return types

We calculate marginal effects as the difference between the expected contribution rate for two realizations of a variable of interest. For example, for H-types the effect of knowing about the heterogeneity and being able to identify the contributor's type requires the comparison between *Full-info* and *No-info* regimes. The marginal effect on average contribution rates across both regimes in phase 1 is given by

$$\begin{aligned} \Delta_{i,t}^{HL} &= E(y_{igt}|x_i, t, High = 1, \textit{No-info} = 0, \textit{Full-info} = 1, phase = 0) \\ &- E(y_{igt}|x_i, t, High = 1, \textit{No-info} = 1, \textit{Full-info} = 0, phase = 0) \end{aligned} \tag{D.1}$$

for which we calculate the expected contribution rates using the parameter estimates of Specification (2) (model in equation (2) to compute $y_{igt}^{\star}$. Finally, we apply the censoring rule in equation (1) to obtain y_{igt}. We compute the effect in equation (D.1) for all individuals who participated in the *Full-info* regime in phase 1 and for each period. We average over all individual effects $1/(NT)\sum_{\forall t,i}\Delta_{i,t}^{HL}$ to obtain the total effect. We simulate the variance of the marginal effects used to calculate the t-values, using 100 Hamilton draws (see Train (2003) and Judd (1999)).[20]

[20] We discard the first 50 draws of a sequence using draws 51-150.