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The Relation between Information and Heterogeneous Ability in Joint Projects – An Experimental Analysis –

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Abstract:
We study voluntary contribution behavior of individuals who vary in their ability to contribute to a joint project under different information scenarios. We investigate a situation with two types who vary only in their external marginal return (low and high). Results of a laboratory experiment suggest that, when group members are not aware of the heterogeneity in their group, both types make the same nominal contributions. When agents are informed about the heterogeneity, contributions increase but differently by type.
High types contribute only more with sufficient social exposure, i.e., when information on the type of the contributor is available. Low types, on the other hand, contribute only more when they are aware of the distribution of types, but have no information on the type of the contributor.

Keywords: Public goods, Voluntary contribution mechanism, Heterogeneity, Information, Norms

JEL Classification: C9, H41

1 Introduction

Team members who contribute to common projects are, generally speaking, not alike. They differ, for instance, in their talents, skills, and qualifications. In some cases, heterogeneous abilities are even necessary to achieve a common goal (Papps et al. (2011)) or to be more productive (Hamilton et al. (2003)). Ledyard (1995, p.159-160) conjectures that contributions to joint projects in heterogeneous groups are very likely to be influenced by the information about heterogeneity that group members have. In this article, we provide empirical support for this supposition and show that not heterogeneity itself, but heterogeneity in interaction with information, impacts contributions.

We employ a public goods experiment, in which we control and vary individual ability and systematically change the information scenarios under which persons make their contribution decisions. In a standard public goods experiment, each member of a group decides whether and how much of his endowment to contribute to a joint project. Each unit an individual contributes increases the joint project by more than a unit but, as the returns of the joint project are shared equally among all group members, the individual receives less than one unit in return. This trade-off illustrates the social dilemma situation as contributing to the joint project is socially efficient but not in the interest of the individual. The return (relative to the costs) that each member receives of one unit contributed to the group project is what the literature has termed the 'marginal per capita return'. Thereby the distinction is made between what other group members receive of a contribution, named 'external return,' and what the contributing member receives, named 'internal return'. In our experiment, we use the external marginal per capita return to model ability: contributions of persons with higher ability generate higher external marginal returns for other group members. In order to ensure that costs of contributions are the same for different levels of ability, we keep the internal returns constant for all group members. We are interested in contribution behavior of individuals in heterogeneous groups that comprise of two ability types, high and low, and this under three levels of information about the abilities of their peers.

Our experiment makes two contributions to the literature. It is the first to study the effect of ability, i.e., external returns, in heterogeneous groups on contributions separately from the costs of contributing, i.e., internal returns. And, secondly, it is the first to investigate how information on team mates' abilities affect contributions.

Our findings can be summarized as follows: When group members are not aware of the heterogeneity in their group, both ability types make the same nominal contributions. When individuals are aware that group members vary in ability, the average propensity to contribute increases. However, we find that the information structure evokes different relative contribution patterns between ability types. When detailed information is available, i.e., on the type of the contributor, high types contribute more than low types. In contrast, low types contribute more when group members are aware of the heterogeneity but contributions cannot be linked to types.

The remainder of the article is organized as follows. Section 2 summarizes related research and places the current study in the literature. Section 3 describes the experimental design and the procedure and gives a descriptive overview of the data. We present our empirical model of individual contribution behavior in section 4 and results in section 5. Section 6 discusses our results in the light of the literature and concludes.

2 Literature

In this section, we summarize related results from the public goods literature and position our paper. Thereby we focus on three lines of research. The first one studies the effect of marginal per capita returns on contributions between groups with different marginal per capita returns and on contributions within groups whose members vary in their marginal per capita return. The second one looks at variations of internal and external marginal returns. And the third one investigates the effect of information on contributions. For comprehensive surveys on public goods in experimental economics beyond this subset of the literature see Ledyard (1995) and Camerer (2003).

2.1 Different marginal per capita returns between homogeneous and within heterogeneous groups

Isaac and Walker (1998) and Bagnoli and McKee (1991) study the effect of marginal per capita returns on contributions. They compare homogeneous groups with high marginal returns to those with low marginal returns. One main result of these studies is that groups with higher marginal returns have a higher propensity to contribute. This finding seems to be robust across studies and for different marginal returns and numbers of group members. Fisher et al. (1995), Palfrey and Prisbrey (1997), Tan (2008) and Reuben and Riedl (2013) study behavior in heterogeneous groups consisting of members with high and low marginal returns to that of homogeneous groups. In line with the research of Isaac and Walker (1998) and Bagnoli and McKee (1991), these studies find that in heterogeneous groups individuals whose contributions have higher marginal returns tend to have a higher propensity to contribute to the public good than do members of the same group with lower marginal returns. There are important differences how these four studies introduce heterogeneity in the return function of the public good that are summarized in Table 1.

The first line of Table 1 presents the return of a standard public goods experiment with homogeneous groups whose members all have the same marginal per capita return (μ). Isaac and Walker (1998) and Bagnoli and McKee (1991) employ this standard return function and vary the marginal return between groups. Fisher et al. (1995), Palfrey and Prisbrey (1997) and Reuben and Riedl (2013), introduce heterogeneity within groups by varying the individual costs of contribution. They assign different marginal per capita returns ($\mu_i \neq \mu_j$)

	Individual return from the public good	Examples
(1)	$\mu \sum_{\forall j} c_j$	Standard game: BM91, IW98
(2)	$\mu_i \sum_{\forall j} c_j$	FISW95, PP97, RR13
(3)	$\sum_{\forall j} \mu_j c_j$	T08
(4)	$\iota c_i + \epsilon \sum_{\forall j \neq i} c_j$	CDP92, GG89, GHL02, PIB01
(5)	$\iota c_i + \sum_{\forall j \neq i} \epsilon_j c_j$	this experiment, with $\iota = 0$

Table 1: Payoff structures of public goods experiments that vary the MPCR.
c_i = contribution of i, μ =marginal per capita return, ι =internal return, ϵ =external return; standard public goods game: $\mu = \mu_i = \mu_j = \iota = \epsilon_i = \epsilon_j, \forall i \neq j$.
BM91=Bagnoli and McKee (1991), CDP92=Carter et al. (1992), FISW95=Fisher et al. (1995), GG89=Goetze and Galderisi (1989), GHL02=Goeree et al. (2002), IW98=Isaac and Walker (1998), PIB01=Packard et al. (2001), PP97=Palfrey and Prisbrey (1997), RR13=Reuben and Riedl (2013), T08=Tan (2008).
For the ease of presentation return functions are normalized by the return from the private good.

within groups, as presented in the second line of Table 1, which results in different benefits from the public good for others. The third line shows how Tan (2008) directly varies the effect a person's contribution has on the benefits of the public good and thus she alters indirectly the costs of contribution.

Results from those six studies suggest that persons react to the costs and benefits of contributing in homogeneous as well as in heterogeneous groups. However, these results confound the effects of costs and benefits. In Tan, the higher marginal benefit comes at lower net costs for higher productivity contributors. And vice versa in the other five studies, lower costs of contribution result in larger benefits from the public good for contributors with higher marginal returns.

To avoid these confounding effects, we allow the marginal per capita return to differ between the contributor and the other group members. We follow Carter et al. (1992) and refer to the marginal return from the public good to the contributor as "internal return" and the marginal return per capita from the public good for other group members as "external return." In our study, ability represents by how much a group member's contribution of one unit increases the public good for others, hence ability is the sum of external returns of members who benefit from one unit contributed by another member. Thereby we look at heterogeneous groups with two distinct levels of ability, high and low. We keep the costs of contributing to the public good constant at one by assigning the same internal return of zero to all group members. The way we model the return from the public good is shown in the fifth line of Table 1.

2.2 Varying internal and external returns

The effects of varying internal and external returns separately has so far only been studied in homogeneous groups, where all members have the same internal and the same external return, however, internal and external return could be different. The fourth line of Table 1 presents the structure of the public goods return with separate internal (ι) and external (ϵ) returns (with $\iota \neq \epsilon$).

Goetze and Galderisi (1989) and Carter et al. (1992) compare groups with low and high internal and external returns in a 2x2 between-subjects design. Both studies find larger contributions when external returns are high, indicating that subjects react even to benefits the public goods provides only for others. Carter et al. (1992). find this effect to be present in the last 5 periods of the experiment at a significance level of 0.01 but to have disappeared in the last period.[1] Packard et al. (2001) replicate partly Carter et al. (1992) and report that even when internal returns are zero, behavior follows the general qualitative pattern in standard public goods of substantial contributions in the first rounds followed by a decay in later rounds. They also find that initial contributions of groups whose members have zero internal and non-zero external return are the same as those of groups with the same (non-zero) internal and external returns. However, the contributions decay faster and contribution levels in the final rounds are significantly lower for groups with zero internal return.

These three experiments employed low and high returns of similar magnitude across experiments – around 0.3 and 0.8 (and 0 for the internal return in Carter et al. (1992).) in a between-subjects design with groups of 4. Subjects interacted only once, either in a one-shot experiment or with rematching groups every period in all experiments, with the exception of Packard et al. (2001), where the groups composition remained the same for 10 periods.

Goeree et al. (2002) study one-shot within-subjects designs with 12 treatments combining internal returns similar to previous studies (either 0.4 and 0.8) but a wider range of external returns (0.4, 0.8, 1.2, and 2.4) and groups with 2 and 4 members. They confirm earlier results that subjects react to an increase of the external return by contributing more. To sum up, these four studies provide evidence that persons in homogeneous groups react positively to external returns, even when internal returns are low – even as low as zero.

[1] Conditional on external returns, contributions are higher when internal returns are higher. Although, only Carter et al. (1992). find this effect to be significant.

2.3 Information

In all studies mentioned above return rates are common knowledge amongst group members. In our study we vary information group members have about the return rates of others. Up to this point in time, little is known about the effect of information on contributions in public goods experiments. However, a few studies exist that vary the aggregation level of the information that group members receive after each round about contributions of others (Sell and Wilson (1991), Croson and Marks (1998), Andreoni and Petrie (2004)).[2] Complementary, Marks and Croson (1999) look at the information about the distribution of valuations for the public good in groups whose members vary in their valuation.

Sell and Wilson (1991) find that information on individual contributions of other group members increases average contributions – compared to providing information on aggregate contributions, or no information at all – and suggest that such behavior can partly be explained by the fact that trigger strategies and positive reinforcement can be better applied when information on individual contributions is available. Andreoni and Petrie (2004) and Croson and Marks (1998) find significantly larger contributions when – in addition to providing information on individual contributions of other group members – individual contributors could be identified, either by a digital photograph or by subject ID numbers.

Marks and Croson (1999) study threshold public goods games with three levels of information that group members have about the valuations of others.[3] Their results suggest that when there is no information on individual contributions of other group members, information on the valuations of public goods in a heterogeneous environment does not alter the aggregate level of contributions.

In our study, we look at three conditions in which we vary the information group members have about the heterogeneity of the external returns of other group members but provide information about individual (nominal) contributions of other group members. In the baseline treatment, group members are informed about their own internal and external returns as well as individual nominal contributions of others in the previous period. In the other two treatments, participants are additionally informed about the internal and external returns of other group members. Furthermore, only in the third treatment, participants are additionally informed about which ability type made a particular contribution. This design

[2] In the field, Ayres et al. (2012) look at the effect of information about energy usage of peers on energy consumption. They report high energy consumers to reduce their consumption after learning about other's consumption.

[3] In all conditions subjects only knew whether the sum of all contributions was above the threshold, in which case the public good was provided. In the other case, every contributor was reimbursed his or her contribution.

allows us to control the level of information about heterogeneity in the external return and to examine how the structure of information affects voluntary contributions in a heterogenous environment.

3 The experiment

The experiment was designed to uncover two kinds of effects: first, the effect of ability on contributions to joint projects in heterogeneous groups and, second, the role of information about this heterogeneity on differences in contributions between types.

3.1 Experimental design

In the experiment, 6 subjects form a group and interact over 15 periods. In every period, each member has to decide how to divide his private endowment of 17 tokens between a private account and a group project. The return of a token contributed to the group project benefits all group members, except the contributor. Benefits depend on the ability of the contributor that could be high or low. Each group consists of 3 high and 3 low ability types, hereafter referred to as H-types and L-types. Internal returns, that represent how much the contributor himself benefits from his own contribution, are zero for all group members.[4] Separating the marginal per capita return into an external and internal return allows to introduce variation in the ability to contribute to the group project while keeping the costs of contribution constant across types.[5] Furthermore, in order to assure that group members face a payoff structure that is symmetric, every individual benefits only from contributions of an equal number of both ability types. Hence, both ability types are equally accounted for in everyone's payoff function.[6] This implies equal payoffs to all members when all members make the same contribution.

We distinguish between 'nominal' and 'effective' contributions. The former refers to how many tokens are allocated from the endowment to the group project, and the latter takes ability into account and measures by how many tokens the group project increases. After

[4]Packard et al. (2001) also employ internal rates that are equal to zero, see our Section 2.2.

[5]In fact, Carter et al. (1992) and Goeree et al. (2002) have shown that contributions are sensitive to both, external and internal returns. We concentrate only on the the effect of external returns, i.e. contributions from which others benefit, and vary those marginal benefits while we keep private costs via the private benefits of contributing constant across individuals.

[6]Consider a group composed of six members; three H-types and three L-types. Individual i's payoff from the public good is based on the contributions by the two other subjects of the same type and two randomly selected subjects of the other type. Consequently, by excluding the contributions of the individual him- or herself and of one member of the opposite type, we maintain the symmetry of individual payoff functions.

each period, all group members' individual nominal contributions to the project are revealed anonymously to the whole group.

The payoff function of group member i can be summarized as follows:

$$\pi_i = w - c_i + \iota c_i + \sum_{\forall j \neq i,k} \epsilon_j c_j \text{ with } \iota = 0; \epsilon \in \{\epsilon_H, \epsilon_L\}, \epsilon_i \neq \epsilon_k; i, k \in \{1, \ldots, n\}$$

with $w = 17$ being the endowment and $w - c_i$ the share kept in the private account. The individual (nominal) contribution c_i increases the joint project for another group member by $\epsilon_i c_i$. In total $(n-2)$ group members benefit from c_i, hence, the effective contribution of c_i to the joint project is $(n-2)\epsilon_i c_i$. The effective contribution of one token represents the 'ability' of $i : (n-2)\epsilon_i$, which depends on the 'external return' ($\epsilon_i \in \{\epsilon_H, \epsilon_L\}$). Member i does not benefit from the own contribution, as the 'internal return' $\iota = 0$. But i benefits from the contributions of others $\sum_{\forall j \neq i,k} \epsilon_j c_j$, excluding one member with the opposite ability than i ($\epsilon_i \neq \epsilon_k; i, k \in \{1, \ldots, n\}$) in order to keep the payoff structure symmetric.

Our treatment variable, the level of information, varies in two ways: first, subjects either do or do not receive information on the distribution of ability types within the group, and second, the feedback information about the nominal contributions of all group members does or does not identify contributors by their type. We study the following information scenarios that are again summarized in the top part of Table 2.

In the *No-info* treatment, subjects know their own ability, i.e., they are informed about their own effective contribution of one token, but not the distribution of types within their group.[7] In the *Part-info* and *Full-info* treatments, the distribution of types is explicitly stated in the instructions. Additionally, the feedback information in the *Full-info* treatment allows subjects to link an individual nominal contribution to the contributor's type. In sum, the three treatments gradually change the level of information about the heterogeneity in ability within the group and whether the ability type of an individual contributor is known or not.

Each information treatment consists of nine groups, each group comprising three H-type and three L-type members. A subject remains the same type and interacts in the same group throughout the whole experiment. Effective contributions per token, i.e. the 'ability to contribute', are 3.99 for H-types and 1.33 for L-types. Hence, the external return of

[7]The instructions never used the word "ability" and left open the possibility that differences in ability between group members may exist. While this approach implies loosing some control over group members' beliefs concerning other members' abilities, it implements the *No-info* treatment, our benchmark treatment, in a way that is as close as possible to the further two treatments.

	Treatments (between-subjects design)		
Information about ...	*No-Info*	*Part-Info*	*Full-Info*
... ability in the group	Own ability	Own ability *and* distribution of ability in group	Own ability *and* distribution of ability in group
... identity of contributors	*without* identification of contributor's type	*without* identification of contributor's type	*with* identification of contributor's type
	Descriptive Statistics: contributions		
Mean	0.42	0.54	0.56
	(0.25)	(0.28)	(0.29)
Mean L-type	0.42	0.59	0.50
	(0.22)	(0.28)	(0.28)
Mean H-type	0.43	0.50	0.62
	(0.28)	(0.27)	(0.28)
N	54	54	54
Periods	15	15	15
Total Nobs	810	810	810

Table 2: Summary of experimental design and descriptive statistics (mean contributions also by type - all as proportion of endowment, standard deviations in parenthesis, number of participants and number of periods.)

one token contributed by a H-type is close to 1, whereas the one of L-types is only close to 1/3.[8] After all group members made their contribution decisions, individual payoffs are computed and group members are informed about their payoffs. Additionally, a table is displayed containing the history of nominal contributions by each group member in all previous periods. The order of individual contributions in the history table is randomized so that contributions cannot be attributed to a specific group member.[9] In the *Full-info* treatment, the history table also displayed the type of each contributor.

3.2 Experimental procedure

The computerized experiment was conducted in eight sessions with a total of 162 undergraduate students (54 per treatment) from Jena University at the laboratory of the Max Planck

[8]Because of our payment scheme, contributions of one group member benefitted 4 other group members, hence the exact external returns of H-types and L-types were 0.9975 and 0.3325. External returns used in our experiment are comparable to those in the literature (see section 2.2).

[9]Participants know that they benefit from contributions of "four other group members" (*No-info* treatment) and "two of each type" (*Part-info* and *Full-info* treatment), but they are not informed about which of the displayed nominal contributions they benefit from. Therefore, in the *Part-info* treatment it is hardly possible to infer the type of the contributor from displayed nominal contributions, or, similarly, to deduce in the *No-info* treatment that there were different types.

Institute of Economics in Jena, Germany. Participants were on average 24 years old and 43% of them were men. Recruitment was performed with the help of an online system (ORSEE, Greiner, 2004), and the experiment was executed using the software zTree (Fischbacher, 2007).

In order to capture some of the individual heterogeneity amongst participants that might influence the behavior in the experiment, participants completed a standard personality questionnaire after the experiment, resulting in a personality index for each participant.[10] The personality index of our participants ranges from one to nine with a mean value of 4.35. A sample copy of the instructions is included in Appendix A.

At the end of each session, subjects received their payoff from the experiment and a show-up fee of 2.5 Euros in cash. Experimental earnings were counted in points and exchanged for Euros, with 80 points corresponding to 1 Euro. Subjects earned on average 5.7 Euros for the 15 rounds, which lasted on average 30 minutes.[11]

3.3 Descriptive Statistics

In total we observe 2,430 contribution decisions for the whole experiment, breaking down into 3 treatments with 9 groups per treatment each with 6 members who decide in every of the 15 periods how much to contribute to the joint project. The bottom part of Table 2 reports the mean of the average individual contributions over 15 periods as a proportion of their endowment. Across the treatments, participants contribute about 50 percent of the endowment. The average contributions in the treatments *Part-info* and *Full-info* appear slightly higher than that in the *No-info* treatment. Table 2 also reports mean contributions by ability type. They appear similar for both types in the *No-info* treatment, but differ for the other two treatments. Aggregated average contributions of L-types are higher in the *Part-info* treatment and lower in the *Full-info* treatment compared to those of H-types.[12]

[10] 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). In particular, our personality index is derived from the individual score in the global personality scale that captures conscientiousness or self-control. This personality index reflects several traits that are associated with the tendency to rely on rules and socially accepted behavior (Conn and Rieke, 1994). The index is expressed in sten-scores that can range from one to ten. Sten values are derived from comparing test scores to the results of a norm population. The average (expected) sten value in the German population is 5.5 with a standard deviation of 2, whereby higher sten-values indicate higher awareness and personal reliance on societal norms and rules.

[11] Each session consists of two phases each lasting 15 periods. In the second phase, groups were confronted with one of the two other treatments in order to study path dependency of contribution behavior. In this article we consider only the first phase. Average earnings for the whole experiment (including both phases) were about 11 Euros.

[12] Aggregation of contributions per group leaves us with 9 observations per treatment and allows us to perform standard non-parametric tests. Ranksum tests however cannot reject the null hypothesis that types within treatments make the same contributions at conventional levels of significance. The lack of significant

The dynamics in the experiment are shown in Figure 1 that plots the average contribution as a proportion of the endowment by treatment across the 15 periods. In all three treatments, the average contribution generally decreases over the course of the experiment, with a stronger decay towards the end. There are noticeable differences across the treatments in how contribution behavior evolves over time. In the *No-info* treatment, contributions continuously decrease over time conform with behavior in other public good experiments. In contrast, in the other two treatments with information about heterogeneity, average contributions seem to increase initially before following the general trend of decay. In the

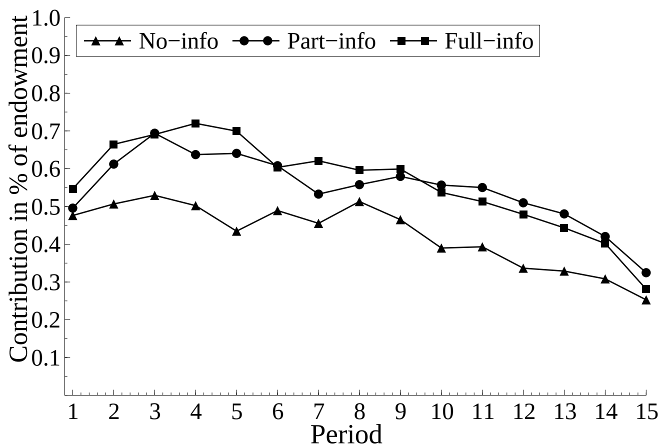

Figure 1: Average nominal contributions as a proportion of the endowment for the three treatments (*No-info*, *Part-info* and *Full-info*)

following, we estimate an empirical model of contribution behavior that allows us to exploit the information at the individual level and to control for individual heterogeneity.

4 Empirical model of contribution behavior

In this section, we present a panel data Tobit model in order to quantify the effect of information and ability on contribution behavior over time while controlling for individual heterogeneity. The choice of the empirical model is guided by the dynamic nature of the data and the fact that contributions are bounded below and on top. Our model allows individual contributions to depend not only on the treatment variables, but also on observable and unobservable personal characteristics as well as time. This way, we are able to provide statistical evidence of how information about heterogeneity affects behavior and to gain

variation in the analysis of aggregated data is not surprising. Though necessary for appropriate non-parametric testing, aggregation neglects information contained in individuals' data. It is very likely that information exerts its effect through dynamic interaction over time.

more insight on how individual contributions evolve over time.

In our model, we describe the proportion that individual i contributes from his or her own endowment in period t, $y^\star_{it}$, as a function:

$$y^\star_{it} = \gamma_0 + \gamma_1 \textit{Part-info}_i + \gamma_2 \textit{Full-info}_i + \mathbf{h}_i\omega + f(t) + \mathbf{x}_i\beta + u_{it} \tag{1}$$

where γ_0 indicates the basic contribution level. We capture the influence of different levels of information about heterogeneity in ability by treatment dummies, with the *No-info* treatment as a baseline. Parameter γ_1 measures the influence of information about heterogeneity and γ_2 measures the effect when ability can be additionally linked to specific contributions. Values of *Part-info* (*Full-info*) are equal to one if i was in treatment *Part-info* (*Full-info*) and zero otherwise. The vector $\mathbf{h}$ contains a dummy variable for ability ($High_i = 1$ if i is a H-type and zero otherwise) and interaction terms of ability and information treatments. The parameter vector ω measures the effects of ability type across treatments. We control for time trends by including $f(t)$, a function of time. 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 ability and other individual characteristics in $\mathbf{x}_i$.

Given the design of the experiment, individual contributions to the joint project are doubly censored, first at the lowest contribution level of 0 units and second at the highest contribution level of 17 units, the endowment in each period.[13] We therefore use a standard regression doubly censored Tobit model to estimate the relation for the latent proportions $y^\star_{it}$ that a group member i contributed (contribution$_i$/17) described in model (1) with

$$y_{it} \begin{cases} = 0 & \text{if } y^\star_{it} \leq 0, \\ = y^\star_{it} & \text{if } 0 < y^\star_{it} < 1, \\ = 1 & \text{if } y^\star_{it} \geq 1. \end{cases} \tag{2}$$

We estimate two specifications of the model in equation (1).[14] Both specifications include the same set of background characteristics and treatment variables but vary in the way time effects are modeled. In specification 1, the time trend is modeled non-parametrically by including dummy variables for each period ($f(t) = \delta_t 1_t$ with 1_t being an indicator function for period t for $t > 1$ and $f(1) = 0$). We found an inverse-U relation between time and

[13]In fact, 23% and 21% of all contribution decisions are at the upper and lower limits, respectively.

[14]We thank Charles Bellemare for providing his tobit model OX code.

contributions and were interested whether this trend is common to both types and apparent in all information conditions. Therefore, in a second specification, we model the time trend as a quadratic function that includes interaction effects with ability and information scenarios:[15]

$$f(t) = \tau_{10} \cdot t + \tau_{20} \cdot t^2 + Interaction(t, High_i, Part\text{-}info_i, Full\text{-}info_i). \quad (3)$$

This allows accounting for both non-linear effects of periods and interactions with the different treatments while minimizing the loss of degrees of freedom.

5 Results

In this section, we report briefly on parameter estimates from both specifications (shown in Tables 3 and 4 in appendix B) and we concentrate on presenting the marginal effects of ability and information on contributions. We also investigate whether and how types react differently to the separate levels of information.

5.1 Parameter estimates

The estimated parameters of specification 1 indicate that information about heterogeneity has a significantly positive impact on contributions ($\gamma_1, \gamma_2 > 0$).[16] We find that women tend to make significantly smaller contributions ($\beta_2 < 0$) and that age and personality index have significant but relatively small negative influences on contributions. All effects are significant at $p = 2.5\%$ or less. Finally, the period dummy coefficients reveal a non-linear time trend, indicating an increase in contribution levels until period three and a strong decrease over the last three periods of the experiment.

Results of specification 2, that incorporates the time trend function (3), reveal that the effect of information materializes largely through dynamic interactions over time and that this effect varies by type. More precisely, information about heterogeneity has a non-linear

[15] The detailed time function is given by:

$$\begin{aligned} f(t) &= \tau_{10} \cdot t + \tau_{11} \cdot t \cdot Part\text{-}info_i + \tau_{12} \cdot t \cdot Full\text{-}info_i \\ &+ \tau_{13} \cdot t \cdot High_i + \tau_{14} \cdot t \cdot High_i \cdot Part\text{-}info_i + \tau_{15} \cdot t \cdot High_i \cdot Full\text{-}info_i \\ &+ \tau_{20} \cdot t^2 + \tau_{21} \cdot t^2 \cdot Part\text{-}info_i + \tau_{22} \cdot t^2 \cdot Full\text{-}info_i \\ &+ \tau_{23} \cdot t^2 \cdot High_i + \tau_{24} \cdot t^2 \cdot High_i \cdot Part\text{-}info_i + \tau_{25} \cdot t^2 \cdot High_i \cdot Full\text{-}info_i \end{aligned}$$

[16] In the *Full-info* treatment, this increase is almost exclusively driven by the more productive type ($\gamma_2 < \omega_2$). In the *No-info* treatment, H-types contribute significantly less compared to their L-type colleagues ($\omega_0 < 0$), but the size of the effect is relatively small and there is practically no difference in this respect when looking at the *Part-info* treatment (ω_1 not significantly different from zero).

effect on individual contributions of both ability types. Instead of the standard monotonic decay, contributions increase before they diminish ($\tau_{11}, \tau_{12} > 0$ and $\tau_{21}, \tau_{22} < 0$). Moreover, additional information counterbalances the declining trend for contributions of H-types ($\tau_{24}, \tau_{25} > 0$). These parameter estimates are not individually significant. In order to test whether their joint effect is significant and to assess the global picture of those individual interactions, we compute expected contributions and calculate marginal effects using our estimated parameters.[17]

5.2 Marginal effects on contributions

Ability

The upper panels in Figure 2 show predicted average nominal contributions as a proportion of the endowment for H- and L-types in each treatment, while the lower panels show the marginal effects of ability on contributions with 95% confidence bounds. The upper left

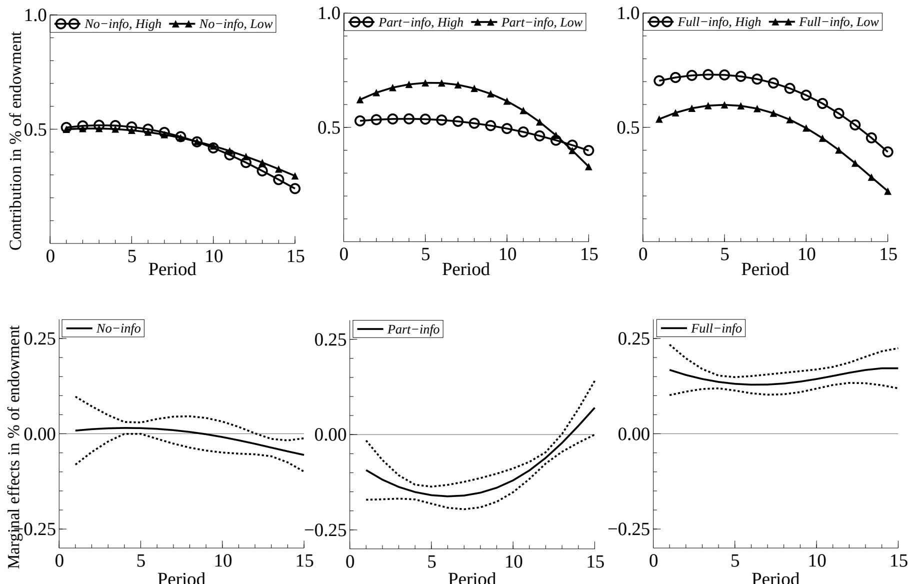

Figure 2: Upper panels: Predicted average contributions (as a proportion of the initial endowment) over time for each treatment and type.
Lower panels: Marginal effects of ability on contributions for each treatment. (The graphs project the difference in relative nominal contributions between H-types and L-types with 95% confidence bounds.)

panel in Figure 2 depicts the *No-info* treatment. The picture suggests that, in the absence of information about heterogeneity, both types make the same nominal contributions that exhibit a similar monotonic decay. The marginal effects analysis for this case, presented in the lower left panel, confirms this observation. We cannot reject the null hypothesis of no

[17]Appendix C presents the details of how we estimated the marginal effects.

difference between types throughout periods 1 to 12. In the last three periods, though, L-types contribute significantly more albeit not very much with around two percentage points.

The other four panels illustrate the case for the treatments with more information. Here, contributions of both types are not monotonically declining but rather parabolic, depicted by the tendency for average contributions to increase initially before following the standard pattern of decay. Moreover, from the lower middle and lower right panels, we learn that contribution behavior differs significantly between types and also between the *Part-info* and the *Full-info* treatments.

The upper and lower middle panels illustrate behavior in the *Part-info* treatment. There, the predicted average contribution of L-types is higher than that of H-types by about 5% to 10% of their endowments. The difference in contribution behavior between H- and L-types is reversed in the *Full-info* treatment, which is illustrated in the upper and lower right panels of Figure 2. When contributions can be linked to the ability type of the contributor, H-types give significantly more than L-types. The difference amounts to around 15% of the endowment and remains constant over time as contributions of both types follow the same time trend.

Information by ability type

Providing information about heterogeneity obviously affects contribution behavior of types in different ways. To test whether these effects of information on contributions by type are significant, we compute marginal effects presented in Figure 3, for H-types in the upper panels and of L-types in the lower panels.

The upper left panel shows that in the first half of the experiment, H-types contribute the same, but from period 8 onwards they contribute more when they have information about the heterogeneity than when they have not. When all group members can additionally link contributions to ability types as shown in the upper right panel, H-types contribute between 10 and 20 percent more of their initial endowment. However, this effect is decreasing over time and in the last two periods, contributions no longer differ significantly. Finally, the upper middle panel indicates that H-types' contributions are around 20 percent higher when they have information about heterogeneity and contributions cannot be linked to ability types compared to when they have not. This effect is relatively stable over time.

We find very different marginal effects for L-types, shown in the lower panels of Figure 3. The lower left and middle panels indicate that information on heterogeneity generally increases the contributions of L-types.The effect is about 2 times stronger when there is

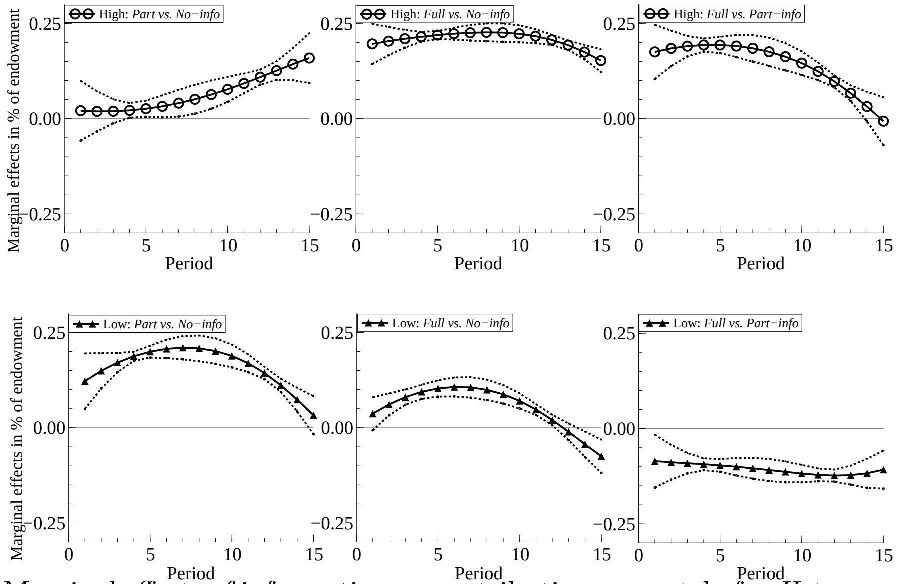

Figure 3: Marginal effects of information on contribution separately for H-types and L-types. (The graphs project the difference in relative nominal contributions between two information scenarios with 95% confidence bounds.)

only information about heterogeneity (lower left panel) compared to the situation wjere contributions can be linked to ability type (lower middle panel). The difference between both effects is significant and visualized in the lower right panel.

6 Discussion and conclusion

This study sheds light on the interplay between the ability to contribute to a joint project and the level of information available on other members ability. Our main results are threefold. First, ability does not affect contributions without additional information on the heterogeneity in ability within the group. Second, average contributions increase with ability, when persons are aware about the heterogeneity and contributions can be linked to the contributors type. Third, contributions are inversely related to ability, when persons are aware of the heterogeneity but cannot link contributions to the contributors type.

Our first result is novel and finds –to the best of our knowledge– no equivalent in the public goods literature. While individual decision experiments on altruism demonstrate that individuals react to changes in the level of the efficiency of giving (Andreoni and Miller (2002), Karlan and List (2007)), we learn from our first result in conjunction with our other results that individuals who contribute to joint projects do not react to their ability when they have no information other than their group members contributions. Only with additional information about others ability to contribute, the different types vary in their levels of nominal contributions. Our result is thus important to understand the behaviour in groups that are heterogeneous with respect to their members ability to contribute to the joint project. It adds to the public goods literature on varying the marginal per capita return that has so far exclusively focused on settings with full information.

Our second finding is in line with the results reported in two strands of the public goods literature. The first separates internal and external returns and the second investigates the effect of varying the marginal per capita return (see Section 2.2). These studies suggest that individuals react to the costs and benefits of contributing in homogeneous as well as in heterogeneous groups when the environment offers full information on individual contributions and the contributors type. What distinguishes our study from these two strands of the literature is that we look at heterogeneous groups in contrast to the literature on homogeneous groups with different external and internal returns. Moreover, in contrast to the hitherto literature on heterogeneous groups where everyone benefits from own contributions, we avoid the confound of costs and benefits of contributing. Our experiment advances the existing literature by isolating the effects of ability to contribute from the cost of contributing –in other words: the effects of the external from the internal return– in heterogeneous groups. From our results we conclude that findings in the existing literature can be partly explained by the full information structure employed in these experiments. Further, under full information, the findings of previous studies on groups with heterogeneous marginal per capita returns are robust to whether or not an individual benefits from own contributions.

Our third finding that low ability types contribute significantly more than high ability types when there is only partial information relates closely to what Fisher et al. (1995) call the "poisoning-of-the-well" effect (p. 265, footnote 11). We find that - depending on which reference treatment we use - we could either denote behaviour as "poisoning-of-the-able" when comparing to the full-information treatment, which is in line with Fisher et al. (1995), or we could call the behaviour "enthusiasm-of-the-less-able" when comparing to contributions in the no-information treatment. As we report in subsection 5.2, this difference between types becomes smaller over time or reverses when full information is available on the type of the contributor. Fisher et al. (1995) report as well the impact of information as their effect disappeared when the experimenters emphasised more strongly the heterogeneity in the groups to their participants.

In summary, we find the effect of ability on contributions is linked to the information group members have about each other. There is strong evidence in laboratory experiments and field studies that information about others affects contribution to public goods (see

Section 2.3). Andreoni and Petrie (2004), who also observe an increase in contributions when individual contributions can be identified, suggest that individuals compare their own contributions to some standard that can be established when contributions of others are known.

Our results complement those of Andreoni and Petrie (2004) by adding the aspect of heterogeneity. We find that in heterogeneous groups types react differently to changes in the information about heterogeneity and to changes in the information about the type of the contributor. As information is likely to foster social comparisons and to clarify a standard, it is not surprising that individuals react to available information. Such a standard may represent a social norm, but which norm is established in groups with heterogeneous agents is an empirical question. From the literature on fairness and justice norms one can derive different contribution norms for heterogeneous environments, based either on efficiency or equity (Konow (2003)). By revealing the type-identity of contributors, type specific standards or norms can emerge more easily, which gives an idea -at least empirically- of what norm is in place in groups with members who differ in their abilities. Given our results, it seems that the standard emerging in our setting is that of efficient contributions, with high ability types making higher nominal, hence, effective contributions. Our experimental results suggest that efficiency motives emerge with sufficient information and social exposure: when identification of ability is linked to individual behaviour, high ability types contribute more than under no information about heterogeneous ability.

We conjecture from our results that efficient contributions by high ability team members result from a social norm rather than representing a private concern. Thus, efficient contributions are more likely in environments with social approval or social pressure, for example when the identity of the contributor is revealed. Whether efficiency is the most desirable norm from the point of view of a policy maker or team members themselves is another important question left for future research.

We conclude by noting that information about heterogeneity, rather than heterogeneity itself, and the extent to which contributions can be identified are crucial to understand how heterogeneity affects public goods provision. We consider our findings important when deciding on the information to be transmitted in teams, for example about the (nominal) performance of individual team members, or when evaluating different disclosure practices of fund raising agencies.

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Appendices

A Instructions (for online appendix)

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 treatment. Differences between treatments 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.

Your payoff from the private account:
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.
Your payoff from the group project:
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.][18] 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.[19]
Please note that four other members of your group benefit from your transfer to the project, but you do not.

One period proceeds as follows:
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

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

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
- 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)].[20] 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 Euros and paid to you immediately. Please remain seated until we call the number of your computer.

Thank you very much for your participation!

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

B Estimation Results

		Specification 1		Specification 2	
Variable	Parameter	Coefficient	T-value	Coefficient	T-value
Constant	γ_0	0.843	8.953	0.934	5.925
Part-info	γ_1	0.210	12.299	0.086	0.428
Full-info	γ_2	0.100	5.955	0.024	0.122
H-type	ω_0	-0.044	-2.422	-0.026	-0.119
H-type *Part-info*	ω_1	-0.012	-0.498	0.037	0.124
H-type *Full-info*	ω_2	0.293	12.801	0.329	1.197
linear Time trend	τ_{10}			0.013	0.276
Part-info	τ_{11}			0.062	1.024
Full-info	τ_{12}			0.054	0.892
H-type	τ_{13}			0.009	0.141
H-type *Part-info*	τ_{14}			-0.070	-0.761
H-type *Full-info*	τ_{15}			-0.033	-0.393
quadratic Time trend	τ_{20}			-0.002	-0.862
Part-info	τ_{21}			-0.005	-1.245
Full-info	τ_{22}			-0.004	-1.166
H-type	τ_{23}			-0.001	-0.286
H-type *Part-info*	τ_{24}			0.006	1.111
H-type *Full-info*	τ_{25}			0.003	0.547
Background characteristics		Yes		Yes	
Time dummies		Yes		No	
Number of Observations		2430		2430	
Number of Parameters		23		21	
	σ_ϵ	0.584	62.539	0.584	64.139
Log-Likelihood value		-33172.7		-33155.7	

Table 3: Estimation results for nominal contribution behavior (dependent variable: proportion that an individual contributes from his or her initial endowment).

		Specification 1		Specification 2	
Variable	Parameter	Coefficient	T-value	Coefficient	T-value
Age	β_1	-0.008	-4.851	-0.008	-4.839
Gender	β_2	-0.239	-19.911	-0.239	-19.840
Personality index	β_3	-0.029	-9.239	-0.029	-9.277
Time dummies	δ_2	0.147	0.933		
	δ_3	0.207	1.509		
	δ_4	0.180	1.364		
	δ_5	0.131	1.084		
	δ_6	0.090	0.790		
	δ_7	0.034	0.301		
	δ_8	0.066	0.524		
	δ_9	0.054	0.458		
	δ_{10}	-0.043	-0.385		
	δ_{11}	-0.048	-0.432		
	δ_{12}	-0.118	-0.973		
	δ_{13}	-0.146	-1.367		
	δ_{14}	-0.225	-2.167		
	δ_{15}	-0.413	-3.808		

Table 4: Parameter estimates of background characteristics and, for specification 1, the time trend.

C Marginal effects of information and of ability types

We calculate marginal effects as the difference between the expected proportion of contribution for two realizations of a variable of interest. For example, the effect of ability on average nominal contributions in the *Full-info* treatment is given by

$$\begin{aligned} \Delta_{i,t}^{HL} &= E(y_{igt}|x_i, t, High = 1, \textit{Part-info} = 0, \textit{Full-info} = 1) \\ &- E(y_{igt}|x_i, t, High = 0, \textit{Part-info} = 0, \textit{Full-info} = 1) \end{aligned} \tag{4}$$

for which we calculate the expected contribution levels using the parameter estimates of specification 2 (model in equation (1) and equation (3)) to compute $y^{\star}_{igt}$. Finally, we apply the censoring rule in equation (2) to obtain y_{igt}. We compute the effect in equation (4) for all individuals who participated in the *Full-info* treatment and for each time 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, that is used to calculate the t-values, using 100 Halton draws (see Train (2003) and Judd (1999)).[21]

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