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by

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Provision of Multilevel Public Goods through Positive Externalities: Experimental Evidence

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Abstract

The provision of public goods regularly embodies interrelated spheres of influence on multiple scales. This article examines the nature of human behavior in a multilevel social dilemma game with positive provision externalities to local and global scales. We report experimental results showing that the behavior in multilevel games is strongly driven by asymmetric conditional cooperation prioritizing local level externalities. Our findings demonstrate how individuals adjust their behavior over time to local conditions. We do not find significant adjustment to the global group average, suggesting that the local group creates a salient reference group for social comparisons in multilevel public goods provision. Our results emphasize the importance of building strong local level commitment when designing institutional responses to promote sustainable provision of globally important public goods like the global climate.

Keywords:

Experiment; Groups; Public good; Spillover Game; Transboundary effects

JEL-classification: H41; C72; C91; C92

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1. Introduction

At the core of numerous social and environmental questions is the quintessential conflict of individual self-interest and social optimality. Understanding how human societies are able to resolve this conflict is not only one of the most pertinent problems of modern economics but also creates a key issue when managing the impact of expanding human population on earth's ecosystems. Global public goods, like the climate, constitute a class of common goods available to all humankind. At the same time, the provision of virtually any global public good embodies interrelated spheres of influence on multiple scales. The nature of the good itself, spatial limits and human made borders regularly create local barriers resulting in production externalities on national, regional and communal scales.

Near-term global climate change and local air quality probably manifest the timeliest and most acknowledged global level social dilemma with important local dimensions. The increase of greenhouse gases in the atmosphere creates a dramatic contingency of changing the living conditions around the globe. However, at the same time, several climate forming agents released by manufacturing and transportation technologies through the incomplete combustion of fossil fuels cause important locally confined problems such as fine-particulate air pollution and traffic congestion. Thus, implementing emission reduction policies that target multilevel air pollutants such as tropospheric ozone and black carbon would potentially lead to effects at multiple scales varying from local health benefits to global climate stability (Shindell et al., 2012). Amidst the myriad of other global goods with local externalities some particularly considerable are locally directed foreign aid that may reduce global terrorism, universities as regionally important employers that create universally accessible knowledge and the preservation of natural wild life habitats with globalized benefits.

This paper reports findings from an experiment featuring voluntary contributions to a multilevel public good. We provide empirical evidence demonstrating that the behavior in a multilevel public goods game is strongly driven by asymmetric conditional cooperation prioritizing local level externalities. Our result show that players adjust their behavior in a repetitive game to local conditions. In contrast, we do not find significant adjustment to the global group average over time, suggesting that the local group creates a salient reference group for social comparisons in multilevel public goods provision.

The study of pure public goods (Samuelson, 1954) and other single scale social dilemmas has long been in the foreground of theoretical and behavioral public economics. There are a growing number of stylized facts describing the behavior in a standard public good situation where positive contributions by individual decision makers are automatically made available to all stakeholders (Ledyard, 1995). In a typical public goods game with a linear payoff function (Isaac et al., 1984), the individually optimal null provision hypothesis is typically rejected and groups attain better outcomes than foreseen by economic models based on narrowly self-interest motivations. Positive contributions to a public good are frequent and may be observed after as many as 50 rounds (Gächter et al., 2008), but typically decline in time from the initial level towards the equilibrium. Consequently, groups regularly fail to achieve socially efficient outcomes, suggesting the importance of selfish motivations. These robust basic results from linear games are regularly maintained even if the uniquely dominant strategy is an interior point in the set of feasible contributions (Isaac and Walker, 1991; Laury and Holt, 2008).

How to overcome the observed sub optimality of voluntary contributions to a common objective has emerged as one of the most fundamental issues in the social sciences. It is well established that theoretical refinements such as the Folk Theorems for repetitive interaction (Aumann, 1981; Axelrod, 1984) and the elements of uncertainty questioning common knowledge of rationality (Kreps et al., 1982) offer equilibrium justifications for positive contributions even among narrowly self-interested players. At the same time, among the vast body of proposed institutional solutions enforceable commitments (Schelling, 1960), self-governed sanctioning institutions (Yamagishi, 1986), costly peer punishments (Ostrom et al., 1992), reputation networks (Nowak and Sigmund, 1998), leadership structures (Güth et al., 2007) and ostracism (Maier-Rigaud et al., 2010) all potentially serve as proximate mechanisms to overcome the problem of free-riding.

In addition to different institutional mechanism, numerous structural and motivational approaches have been implemented to study the impact of intergroup competition on human cooperation (Bornstein and Ben-Yossef, 1994). Notably, individually optimal behavior can be harnessed to produce social efficiency, when individual payoffs are made contingent upon the relative ranking or absolute difference between the competing groups. At the same time, various laboratory (Bornstein and Erev, 1994) and field (Erev et al., 1993) experiments on intergroup competition

show increased cooperation rates even in cases where narrow self-interest denies any voluntary contributions.

Over the recent years, a number of social preference theories assuming a wider notion of self-interest have been proposed to explain the gulf between the standard economic models of selfish behavior and empirical observations. These theories can roughly be classified into outcome-based other-regarding preference models (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and intention-based models of reciprocal behavior (Fehr and Gächter, 2000; Falk and Fischbacher, 2006). Common to these theories is that they allow for voluntary contributions to public good given positive expectations about others' cooperativeness. This empirically validated phenomenon often characterized as conditional cooperation (Fischbacher et al., 2001) suggests drastically different policy implications than the standard economic models of selfish behavior. However, evidence supporting the aptitude of social preference theories and conditional contribution to describe the nature of voluntary public good provision is limited to single dimensional dilemmas. Little is known about the human behavior in an important class of multidimensional public good provision problems creating production externalities on local and global scales.

The study of voluntary contribution mechanisms has so far largely ignored the potential of joint production benefits on multiple scales. A notable exception is provided by Cornes and Sandler (1984) in their seminal theoretical contribution towards understanding the nature of impure public goods with interdependent private and public good characteristics. The simultaneity of local and global beneficiaries in public good provision is recognized only in very few behavioral inquiries. Blackwell and McKee (2003) and Fellner and Lünser (2008) both conduct experiments with mutually exclusive local and global group accounts. These studies find an innate bias towards the local group. Furthermore, both studies find that the relative returns from substitutable public goods accounts significantly affect the target of voluntary contributions. Wang et al. (2011) construct a theoretical model to study the evolution of cooperation in two interdependent communities. They demonstrate the potential success of cooperative strategies when the imitation strength between communities is strong enough. Buchan et al. (2009) suggest that the individual propensities to contribute to local and global accounts in social dilemmas are correlated with global attitudes measured through the Globalization Index survey.

Our paper importantly differs from these studies as we introduce a model based on positive provision externalities, making contributions to public good complemen-

tary at the local and global scales. In our view, the advantage of our model is that the paradigmatic conflict between individual optimality and collective efficiency is transformed into a situation where narrow self-interest can be questioned both by local and global level efficiency. This allows us not only to study the effect of positive externalities but the relative importance of local and global groups for conditionally cooperative provision strategies.

Closer related to our study is a paper by Engel and Rockenbach (2009) experimentally implementing a linear public goods game with inactive players who may either benefit or get hurt by positive contributions to a group account. Our study differs from this paper in several important aspects as all players in our model are active stakeholders who have a possibility to contribute to a multilevel public good. This allows us not only to study the importance of reciprocity in general but also renders it possible to disentangle the relative importance of previous contributions in local and global groups. Given our focus to model voluntary contributions to a multilevel public good, it appears important that stakeholders both at the local and global scales are actively involved in the process of public good provision. This active participation of all actors is also reflected in the examples we provide to motivate our modeling strategy.

Finally, our study connects to a long-standing literature investigating group size effects in public goods provision. We contribute to this string of literature by providing new empirical evidence from a situation where a smaller group of players is nested within a larger group of beneficiaries. Our results show that contribution levels in all treatments stay strictly between the level optimal for a three-player local group and the selfish optimum. In addition, we find that players react to higher shares of globally efficient contributions by lowering their contributions in the subsequent round, supporting previous findings from single level games showing that larger group size may lead to decreasing individual contributions (Bagnoli and McKee, 1991). Consequently, our findings contrast with the results by Isaac and Walker (1988) and Isaac et al. (1994) which have questioned the behavioral relevance of pure numbers-in-the-group effect.

In our study, individual decisions are repetitively realized. We provide appropriate feedback about the individual decisions in the local and global groups between rounds. This allows for various forms of path dependence. To capture the nestedness of global and local level stakeholders, we inspire group identities not only by labeling but also by (i.) stronger positive payoff interdependencies within the

local group than the global group and by (ii.) symmetry within local groups and asymmetry across local groups. In comparison to other social dilemma games like, for instance, the frequently implemented linear public good game, we preserve that all players have a dominant strategy regardless of other players' behavior. In other words, both local and global efficiency levels require individually costly choices. However, all benchmark contribution levels lie in the interior of the feasible choice set. That is, participants may deviate from each benchmark by choosing either lower or higher individual provision levels. This has the advantage that pure noise in decision making is equally possible below and above the benchmark levels.

The necessary non-linearity is reduced to provision costs, determined by simple quadratic cost functions. The spillovers from an individual choice to local and global levels are determined by linear functions similar to linear public goods games. While a multilevel game with positive spillovers may have a lot of parameters, in our experimental implementation individual and group characteristics are restricted to include three dimensions. Each player is defined by one cost parameter, one local and one global productivity parameter. Since the local group identity is inspired by individual symmetry we examine a social dilemma game determined by six parameters: two cost parameters and two different sets of local and global parameters. We refer to this game as a Spillover Game (SG).

The remainder of the paper is organized as follows: in section 2, we introduce the characteristics of the Spillover Game. Section 3 describes the experimental implementation and protocol in more detail. In section 4, we describe some theoretical considerations and develop behavioral conjectures. After describing and analyzing the data in section 5, section 6 concludes.

2. Spillover Game

Let $N = \{1, \dots, n\}$ with $n \geq 4$ denote the set of players $h = 1, 2, \dots, n$, which is partitioned into two subgroups $I = \{i_1, \dots, i_{m_i}\}$ and $J = \{j_1, \dots, j_{m_j}\}$ with $m_i, m_j \geq 2$ and $m_i + m_j = n$. We use notation $h \in N$ for any player as well as $i \in I$ and $j \in J$ when referring to players in a certain subgroup.

Player h 's strategy is her provision quantity $q_h (\geq 0)$. Contributing an amount q_h costs

$$C_h(q_h) = \frac{q_h^2}{d_h} \text{ with } d_h > 0 \text{ for all } h \in N. \quad (1)$$

Player h gains linearly from the provision amounts of all players according to a payoff function

$$U_h = \sum_{k=1}^n \alpha_k^h q_k - C_h(q_h) \text{ with } \alpha_k^h > 0 \text{ for all } h \in N. \quad (2)$$

More specifically, we speak of a Spillover Game (SG) when for all $h \in N$

$$\alpha_h^h > \alpha_i^h > \alpha_j^h \geq 0 \text{ if } h \in I;$$

$$\alpha_h^h > \alpha_j^h > \alpha_i^h \geq 0 \text{ if } h \in J.$$

The first inequalities capture the regularity that players profit most from their own contributions; the second inequalities express the greater spillover toward local subgroup members. The last inequalities render individual contributions globally effective.

Our implementation of the Spillover Game is based on parameters

$$\alpha_h^h = 1 \text{ for all } h \in N$$

$$\left. \begin{array}{l} \alpha_h^i = \bar{\alpha}_h \text{ for all } h \in I \\ \alpha_h^j = \underline{\alpha}_h \text{ for all } h \in J \end{array} \right\} \text{ with } 1 > \bar{\alpha}_h > \underline{\alpha}_h > 0 \text{ for all } i \in I,$$

$$\left. \begin{array}{l} \alpha_h^j = \bar{\alpha}_h \text{ for all } h \in J \\ \alpha_h^i = \underline{\alpha}_h \text{ for all } h \in I \end{array} \right\} \text{ with } 1 > \bar{\alpha}_h > \underline{\alpha}_h > 0 \text{ for all } j \in J.$$

Thus, each player $h \in N$ is characterized by her attributes

$$(d_h, \bar{\alpha}_h, \underline{\alpha}_h)$$

specifying her cost type d_h and how strongly she affects members of her local ($\bar{\alpha}_h$) and her global ($\underline{\alpha}_h$) group. In this setup, opportunism in the sense that players $h \in N$ are only motivated by their own material payoff U_h obviously implies for a representative player h provision quantity

$$(0) \quad q_h^* = \frac{d_h}{2}. \quad (3)$$

If players , however, are motivated to maximize the joint payoff of their own (local) group members, but ignore the material welfare at the global level, the payoff function for a representative player can be written as

$$\begin{aligned} & [1 + (m_i - 1)\bar{\alpha}_h]q_h - C_h(q_h) \text{ if } h \in I, \\ & [1 + (m_j - 1)\bar{\alpha}_h]q_h - C_h(q_h) \text{ if } h \in J. \end{aligned}$$

Thus, the desire to maximize local efficiency predicts individual provision quantities

$$(LE)c_h^+ = \begin{cases} \frac{[1+(m_i-1)\bar{\alpha}_h]d_h}{2} & \text{for } h \in I \\ \frac{[1+(m_j-1)\bar{\alpha}_h]d_h}{2} & \text{for } h \in J. \end{cases}$$

Global efficiency does not restrict efficiency concerns to one's subgroup but suggests to consider all externalities by maximizing the joint payoff of all global group members. In this case, the payoff function can be written as

$$\begin{aligned} & [1 + (m_i - 1)\bar{\alpha}_h + m_j\alpha_h]q_h - C_h(q_h) \text{ if } h \in I \\ & [1 + (m_j - 1)\bar{\alpha}_h + m_i\alpha_h]q_h - C_h(q_h) \text{ if } h \in J. \end{aligned}$$

Thus, the optimal provision quantities maximizing the global efficiency are

$$(GE)c_h^\oplus = \begin{cases} \frac{[1+(m_i-1)\bar{\alpha}_h+m_j\alpha_h]d_h}{2} & \text{for } h \in I \\ \frac{[1+(m_j-1)\bar{\alpha}_h+m_i\alpha_h]d_h}{2} & \text{for } h \in J. \end{cases}$$

In the experiment we realize the within group symmetry and across group asymmetry by setting

$$d_i = 4 \text{ and } \bar{\alpha}_h, \alpha_h \text{ such that } 1 > \bar{\alpha}_h > \alpha_h > 0 \text{ for all } h \in I,$$

$$d_j = 6 \text{ and } \bar{\alpha}_h, \alpha_h \text{ such that } 1 > \bar{\alpha}_h > \alpha_h > 0 \text{ for all } h \in J.$$

When setting $m_i = m_j = 3$ one, however, still derives the same efficiency benchmarks for both groups when imposing

$$(LE') (1 + 2\bar{\alpha}_i)4 = (1 + 2\bar{\alpha}_j)6 \text{ for local efficiency (LE) and}$$

$$(GE') (1 + 2\bar{\alpha}_i + 3\alpha_i)4 = (1 + 2\bar{\alpha}_j + 3\alpha_j)6 \text{ for global efficiency (GE).}$$

Table 1: Experimental treatments with their spillover parameters

Treatment		Cost parameter	Individual effect	Local spillover	Global spillover
LE-GE	Type X	4	1	0.6	0.3
	Type Y	6	1	0.4	0.25
LE	Type X	4	1	0.6	0.3
	Type Y	6	1	0.4	0.3
GE	Type X	4	1	0.5	0.4
	Type Y	6	1	0.5	0.2
C	Type X	4	1.2	0.5	-
	Type Y	6	1.2	0.5	-

3. Experimental implementation and procedure

The main characteristic of our experimental design is the spillover of voluntary contributions to local and global groups. In our experiment, six subjects form a global group which is partitioned into two local groups of equal size. In the following, we refer to these distinct but interdependent groups as X and Y and to players belonging to a particular subgroup as X-players and Y-players. Individual contributions to the multilevel public good, q_h , are restricted to integers ranging from 0 to 10.

We collect the choices of X- and Y-players in four different treatments that vary in spillovers between local and global groups (Table 1). In our control treatment (C), subgroups are structurally independent. In treatments with interdependent subgroups neither individually optimal nor locally or globally efficient provision quantities change between treatments (Table 2). Our experimental treatments are implemented such that in treatment LE-GE the total efficiency of public goods provision is equal between subgroups at locally (LE) and globally (GE) efficient provision levels. In treatments LE and GE, the total efficiency is equal either at the local (LE) or global level (GE), respectively. We keep the total productivity of Y-players constant between the control treatment (C) and treatment GE.

We implement all treatments applying both stranger and partner designs similar to Andreoni (1988). All participants play 15 rounds under both matching protocols. At the end of each experimental session, one 15 round block of cumulative earnings is randomly chosen to determine monetary payoffs. The random draw is performed by one of the participants through a coin flip. The order of matching protocols is counterbalanced across sessions to control for possible sequence effects. We are interested in the stranger protocol as it arguably can be seen as a repeated one-shot

Table 2: Benchmark provision by player type and treatments

Treatment		Individual interest	Local efficiency	Global efficiency
LE-GE	Type X	2	4	6
	Type Y	3	6	8
LE	Type X	2	4	6
	Type Y	3	6	8
GE	Type X	2	4	6
	Type Y	3	6	8
C	Type X	2	4	4
	Type Y	3	6	6

game allowing to study the basic behavioral motivations of multilevel public goods provision. At the same time, the partner protocol renders it possible to investigate the evolution of public goods provision in stable local and global constellations over time.

Participants receive feedback at the end of each round summarizing the total amount of received spillovers from both subgroups as well as information about the individual behavior of all players both in their local and global groups. The order in which individual contributions are displayed is reshuffled after each round in order to discourage any kind of reputation formation.

The experiment was conducted at the laboratory of the Max Planck Institute of Economics in Jena (Germany) and programmed using the z-Tree (Fischbacher, 2007). A total number of 240 subjects in eight sessions participated in the experiment. The vast majority of 140 female and 100 male subjects were undergraduate students (Mean age: 23.2 years, Min: 18 years, Max: 44 years) at the Friedrich-Schiller University in Jena studying a range of different disciplines. Upon arrival participants were randomly assigned to their cubicles preventing communication and visual interaction. Participants received detailed instructions on paper. Instructions were read aloud including the examples. The experiment began after all participants had finished reading the instructions and found correct answers to all questions testing participants' understanding of the game rules. After the experiment participants were paid privately in cash according to their performance. One session lasted on average 90 Minutes. Earnings per participant ranged from 8 to 26 Euro with an average of 15 Euro.

4. Theoretical considerations and behavioral conjectures

Given our model of multilevel public good provision, locally and globally efficient contribution levels require individually costly choices. In other words, individuals solely interested in maximizing their monetary gains have a dominant strategy regardless of other players' behavior. Under the common knowledge of rationality the behavior of narrowly self-interested individuals in a finitely repeated Spillover game is described by unique stationary equilibrium. We refer to this equilibrium as an opportunistic benchmark. Contribution levels described by the opportunistic benchmark imply that individuals are not influenced by local or global efficiency concerns. Likewise, we do not expect to find any treatment differences, if individual behavior fully conforms to the opportunistic benchmark. The expected behavior of narrowly self-interested individuals in a multilevel public goods game with positive externalities can be summarized as:

(H1): Observed behavior does not systematically deviate from the opportunistic benchmarks.

Various recent attempts to explain the pro-social behaviors of economic actors have build preferences for efficiency into the underlying utility function (Charness and Rabin, 2002). This approach has largely been motivated by experimental evidence showing that individuals regularly make choices that increase group efficiency, even at the cost of sacrificing their monetary gains (Charness and Rabin, 2002; Engelmann and Strobel, 2004). Closely related to potential efficiency concerns, is the notion of altruistically motivated players who are expected to increase their contributions to common good when benefits are shared by a larger group of recipients (Anderson et al., 1998). Efficiency concerns as such and potential psychological costs from contributing less than is required to reach an efficient outcome (Corazzini et al., 2010) may explain positive contributions to public goods.

However, these considerations do not differentiate between local and global efficiency. Consequently, one of the main objectives of our study is to provide empirical evidence about the relative importance of efficiency concerns with respect to local and global group optima. If global efficiency concerns are an important determinant of voluntary contributions to multilevel public goods, individual contributions are expected to be closer to the globally optimal level when global spillovers increase in contrast to a control condition that holds all the other factors constant. Given

the potential importance of global efficiency concerns, we hypothesize that the aggregate contributions to public good by efficiency minded players increase when the magnitude of spillovers to global group is increased. In other words,

(H2): Increased marginal rate of return to global welfare increases voluntary contributions to a multilevel public good.

A complementary explanation to positive voluntary contributions to public goods is provided by a growing number of social preference theories paying attention to the stylized facts that demonstrate systematic deviations from the narrow self-interest. Theories highlighting the importance of interdependent social preferences (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and the power of reciprocal intentions (Fehr and Gächter, 2000; Falk and Fischbacher, 2006) in human behavior are examples of theoretical considerations of economic equality. However, relatively little interest has been devoted to understand how reference groups for social comparisons are formed and how individuals' potential concerns for equality and efficiency evolve in strategic environments. Consequently, a recent line of research has began to investigate this question, positing that individuals develop more other-regarding towards their own group members in contrast to individuals outside their own group (Charness et al., 2007; Charness and Jackson, 2009; Sutter, 2009). The present study extends the minimal group paradigm (Tajfel, 1982) by strengthening group identity through asymmetric material payoffs. We contribute towards understanding the development of other-regarding preferences in a situation where several potential reference groups are nested at multiple scales.

A crucial feature of our game is that both free-riding and positive contributions of equal size between player types generate a difference in material payoffs between player types, advancing those players with lower provision costs (Y-type). This difference in payoffs between player types can, however, be diminished in treatments with positive spillovers from local groups to global level by contributions above the opportunistic benchmark. This opportunity does not exist in the absence of global externalities (Treatment C). If concerns for inequality between different player types are a powerful determinant of individual behavior in our experiment of multilevel public goods provision, keeping the other factors constant the payoff difference between X- and Y-type of players is expected to be smaller in the presence of positive externalities (treatment GE) than in a situation where no means to diminish differ-

ence in material payoffs exist (treatment C). In other words,

(H3): Players primarily motivated by concerns for economic equality reduce the payoff inequality between player types in the presence of positive spillovers.

5. Results

In order to characterize the nature of voluntary cooperation in a multilevel public good game with positive externalities, we organize the discussion of our results as follows. We begin with general observations describing the temporal patterns of voluntary contributions by player type and treatment. This descriptive analysis is followed by a more subtle statistical analysis to test our behavioral conjectures. Finally, we describe the most important determinants of individual behaviour examining how players adjust their contributions to information about local and global level contributions from previous rounds. When analyzing the data, we refer to labels assigned to each treatment in section 3 or drop the labels entirely when analyzing data pooled across treatments. For testing the hypotheses and comparing aggregated individual contributions, we report non-parametric test values performed on mean contributions of independent groups of players. For the investigation of adjustment to past behaviour in local and global groups we apply various fixed effects models to incorporate the panel structure of the data.

5.1. *The nature of cooperation in the Spillover Game*

Figure 1 sets the stage for our analysis, depicting the temporal pattern of average contributions by player type across the treatments with positive externalities. Figure 1 conveys an unequivocal message. The observed average rate of public good provisions is in all treatments strictly between the local efficiency benchmark and selfish optimum. This finding provides first suggestive evidence about the importance of local level beneficiaries for multilevel public goods provision. At the same time, our finding clearly challenges the explanation of voluntary cooperation by decision errors (Andreoni, 1995; Palfrey and Prisbrey, 1997) in a multilevel environment as contributions below the opportunistic benchmark level are rare even for X-players who are disadvantaged due to their higher provision costs.

Figure 1 about here

Despite the fact that all benchmark contribution levels are located in the interior of players' feasible choice set, their location differs based on player type. It can be inferred from figure 1 that Y-players deviate more markedly from the locally efficient level of contributions due to its relative location in the upper half of the decision space. This happens despite the fact that the total production efficiencies remain constant across player types and benchmark predictions. In other words, the location of the benchmark relative to the individual choice set appears to affect aggregate contributions to a multilevel public good. This observation is consistent with the earlier evidence from single level nonlinear public good experiments (Isaac and Walker, 1998). We examine the importance of this finding further when testing the explanatory power of outcome based other-regarding preference theories for our findings.

Figure 1 further suggests declining contribution rates. This declining trend is confirmed in table 3, reporting Pearson correlation coefficients between rounds and their respective average contributions for each independent observation. We do not find evidence for substantial order effects between matching protocols. The steady decline in positive contributions, prototypical for voluntary contribution mechanisms, is observed irrespective of matching protocol or player type. Table 3 provides further an overview of individual contributions and earnings averaged across all rounds. The difference between fixed group interaction and randomly repeated single-shot iterations is tested by comparing a set of observations within subject under both matching protocols. We reject the conjecture that there is no difference between partner and stranger design (Wilcoxon signed-rank test; $Z=-3.267$, $n=18$, $p=0.001$). As a result of this behavioral pattern, the local efficiency benchmark is more closely approximated by stable groups than randomly changing groups.

5.2. Tests of hypotheses

Based on the discussion of various theories of human behavior in strategic situations in section 3, we provided three potential behavioral conjectures to describe the nature of voluntary contributions in a multilevel public goods environment. We first test the relevance of monetary payoffs maximizing self-interest. The fact that average contributions are strictly above the opportunistic benchmark in Figure 1 questions narrow self-interest as a primary determinant of voluntary contributions in our experiment. We confirm this impression statistically by testing the average contributions in the last round (round 15) against the opportunistic benchmark. Table 4 reports average contributions in last round of iterative interaction. The null

Table 3: Overview of average contributions, time trends and treatment differences in treatments with positive global externalities

	Stranger			Partner		
	Average Cont.	Average Earnings	Time trend	Average Cont.	Average Earnings	Time trend
Type X	2.80 (.30)	6.57 (1.02)	-.22**	3.06 (.76)	6.99 (1.27)	-.27**
Type Y	3.92 (.15)	7.13 (0.59)	-.19**	4.25 (0.73)	7.43 (0.83)	-.21**
Treatment difference	N.A	N.A	N.A	3.357 (df=2) p=0.187	3.520 (df=2) p=0.172	2.468 (df=2) p=0.291

Average contributions and earnings in ECUs, standard deviation in parenthesis. Time trend over all rounds is indicated by the Pearson correlation coefficient. Treatment differences are tested applying Kruskal-Wallis (2-sided) test. Data are analyzed at the group level to account for the independence of observations. **Significant at 1%; *Significant at 5%; +Significant at 10%.

hypothesis of no difference between theoretical benchmark and observed behavior in the last round of repeated interaction is rejected except for one case (Y-players, stranger matching). Likewise, by testing the difference of local efficiency benchmarks and aggregate behavior in the first decision round, we reject the importance of unconditional local efficiency concerns as a predictor of aggregate contributions. In other words, on average all observations lie in the range between local efficiency and individual opportunism, which, however, do not provide accurate descriptions for aggregate behavior. We reject the importance of narrow self-interest as a sole explanation for voluntary contributions in a multilevel public goods game.

Our second conjecture envisaged concerns for efficiency as a potential determinant of voluntary contributions. We construct a rough test to examine the influence of varying externality parameters for the voluntary contributions by comparing the behavioral response under the three different treatments with payoff interdependent subgroups (LE, GE and LEGE). The Kruskal-Wallis test for the equality of population medians between the three treatments does not allow us to reject the null hypothesis that no differences exist between treatments (Table 3). This test creates only a crude measure about the importance of global efficiency concerns as the size of externalities both to local and global level vary between treatments. However, examining the differences on a more subtle level, a comparison of treatments LE and LEGE creates a particularly clean test of efficiency concerns as we only vary the size of global externalities generated by Y-players between treatments. After performing a pairwise test to examine the behavior of Y-players between LE and LEGE (Mann-

Table 4: Average contributions to a multilevel public good by player type during the first and last round of 15-round interaction. Observed values are tested against the theoretical benchmarks for local efficiency (round 1) and opportunistic benchmark (round 15)

	Average contribution (Round 1) - Local prediction		Average contribution (Round 15) - Opportunistic prediction	
	Stranger	Partner	Stranger	Partner
Type X	3.26 (.80) (n=6) p=0.075	3.50 (.92) (n=18) p=0.046	2.42 (.24) (n=6) p=0.028	2.54 (.72) (n=18) p=0.003
Type Y	4.49 (.45) (n=6) p=0.028	4.83 (1.20) (n=18) p=0.003	3.16 (.27) (n=6) p=0.141	3.54 (.80) (n=18) p=0.006

Average contributions (and standard deviations) in the first and last round. Deviations from opportunistic and local efficiency predictions are tested applying Wilcoxon signed rank test (2-sided) against the null hypothesis that no difference exists. All data are analyzed at the group level to account for the independence of observations.

Whitney exact test; $Z=-1.210$, $n=18$, $p=0.234$), we do not find evidence suggesting a significant response to changing global externalities. We find that after keeping the other factors constant the provision of a multilevel public good is not influenced by global efficiency concerns.

Our third conjecture relies on the fact that the experimental implementation of our model generates a difference in material payoffs between player types, favoring players with lower costs (Y-type). This difference in payoffs between player types can be diminished in treatments with positive spillovers from local to global groups, but not in the absence of payoff interdependency between subgroups (Treatment C). We test the importance of outcome-based inequality reduction as a decisive factor of multilevel public good provision by comparing the payoff differences between players X and Y in treatments C and GE. In contrast to the possibility of reducing the payoff difference between player types, the difference in payoffs between player types does not diminish in case of interdependent subgroups, but increases independent of the matching protocol (Type-Y - Type-X in C-stranger = 2.50, in C-partner = 2.49, in GE-stranger = 1.73 and GE-partner = 1.99). We conclude that the introduction of payoff interdependency between the player types (subgroups) does not reduce inequality between players in the global group.

5.3. Determinants of individual behavior

After discussing various possible hypotheses to explain the observed behavior, we finally investigate the multifaceted nature of voluntary contributions at the in-

Table 5: Fixed effects regression models on the determinants of contribution to a multilevel public good in treatments with positive externalities

	Dependent variable					
	Contribution Stranger			Contribution Partner		
Fixed effects	(1)	(2)	(3)	(4)	(5)	(6)
Ingroup t-1	0.172*** (.022)	0.186*** (.037)	0.190*** (.042)	0.334*** (.050)	0.309*** (.080)	0.267*** (.091)
Outgroup t-1		0.062 (.045)	0.068 (.052)		0.044 (.073)	-0.018 (.067)
Ingroup t-1 x period		-0.011** (.004)	-0.011** (.005)		-0.010 (.006)	-0.005 (.008)
Outgroup t-1 x period		-0.004 (.005)	-0.004 (.006)		-0.006 (.007)	0.002 (.007)
Period			-0.004 (.019)			-0.044* (.024)
Constant	2.586*** (.072)	2.718*** (.116)	2.689*** (.191)	2.336*** (.175)	2.744*** (.247)	3.110*** (.316)
Groups	-	-	-	30	30	30
Individuals	180	180	180	180	180	180
Observations	2520	2520	2520	2520	2520	2520
R2 within	.025	.061	.061	.060	.100	.100
R2 between	.076	.043	.043	.233	.228	.228
R2 overall	.039	.042	.042	.142	.135	.135
$Prob > \chi^2$	< .000	< .000	< .000	< .000	< .000	< .000

Fixed effects regression coefficients, robust standard errors in parenthesis. In models 1-3, dependent variable is individual contribution under stranger matching, in models 4-6 under partner matching. ***Significant at 1%; **Significant at 5%; *Significant at 10%.

dividual level by estimating various regressions models. Table 5 presents models examining the importance of local and global level feedback to the provision of the multilevel public good. Model 1 serves a starting point of our analysis, including only the amount of received local level externalities. We find a strong tendency to react to the preceding interaction within the local group. The higher the amount of received externalities from the local group, the more players contribute in the following round. Models 2 and 3 include received local and global level externalities from the preceding round. Out of the received externalities only those diffusing from the local group members prove to be significant determinants of individual behavior. Furthermore, it should be noted that the received externalities from the local group members are only modestly correlated ($p = .208$) with the received flow of externalities from the other subgroup, marginalizing the potential influence of multicollinear independent variables.

Models 2 and 3 allow us to study the influence of independent variables in time. First, model 3 confirms the significant decline in average contributions over time.

Table 6: Fixed effects regression models examining how individual adjust their behavior to past differences when contributing to a multilevel public good in treatments with positive externalities

	Dependent variable					
	Cont.(t) - Cont.(t-1) Stranger			Cont.(t) - Cont.(t-1) Partner		
	(1)	(2)	(3)	(4)	(5)	(6)
Fixed effects						
Difference to ingroup mean	0.641*** (.022)	0.147*** (.055)	0.141*** (.055)	0.726*** (.051)	0.226** (.104)	0.195*** (.064)
Difference to outgroup mean		0.001 (.057)	-0.016 (.057)		-0.061 (.090)	-0.079 (.066)
Share of global optimum		-4.724*** (.172)	-4.908*** (.200)		-6.354*** (.579)	-6.902*** (.302)
Ingroup minimum			0.059*** (.035)			0.125*** (.037)
Outgroup minimum			-0.007* (.036)			-0.039*** (.036)
Period		-0.038*** (.005)	-0.039*** (.005)		-0.058*** (.008)	-0.061 (.006)
Constant	-0.077*** (.022)	2.764*** (.115)	2.750*** (.119)	-0.075*** (.000)	3.270*** (.290)	3.280*** (.141)
Groups	-	-	-	30	30	30
Individuals	180	180	180	180	180	180
Observations	2520	2520	2520	2520	2520	2520
R2 within	.273	.471	.472	.302	.474	.477
R2 between	.048	.046	.047	.117	.038	.041
R2 overall	.212	.245	.245	.231	.245	.253
$Prob > \chi^2$	< .000	< .000	< .000	< .000	< .000	< .000

Fixed effects regression coefficients, robust standard errors in parenthesis. In models 1-3, dependent variable is change from round t-1 to t in individual contribution under stranger matching, in models 4-6 change from round t-1 to t individual contribution under partner matching. ***Significant at 1%; **Significant at 5%; *Significant at 10%.

More importantly, models 2 and 3 include a time-dependent interaction terms of received local and global externalities. Estimated models show that there is a time trend in the relative importance of received local externalities. The negative coefficient of an interaction variable for received local externalities and time-trend indicates attenuating impact of local externalities in the decision process over time. In other words, players confront a vicious circle of declining contributions and weakening impact of local level feedback, resulting in a decline towards the opportunistic benchmark level of multilevel public good provision. In sum, our results provide strong evidence that the behavior is driven by conditionally cooperative motives focusing on local level interaction.

We study the phenomenon of locally determined conditional cooperation further in models that examine how players adjust their behavior to past differences between their own contributions and observed contributions on local and global levels. Table

6 displays models investigating how players react to past differences to their local and global group members as well as to the global efficiency benchmark. We construct the independent variables indicating differences to a relevant group average such that the payoff difference is positive if player has outperformed other group members by contributing less than the average. We find strong evidence that players adjust their behavior to the past difference between their previous contribution and local group average (table 6). In contrast, we do not find significant adjustment to the global group average over time.

The importance of locally driven conditional cooperation based on a nested group structure is further elaborated by examining the impact of past minimum contributions in local and global groups. We find that players do not reduce, but increase, their contributions given the past in-group minimum. This result further stresses the importance of adjustment to the local group mean. In contrast, players react negatively to the outgroup minimum, decreasing their contributions to the multi-level public good after observing a low minimum contribution at the global scale. Finally, we study the impact of global efficiency concerns for multilevel public good provision by considering a variable that represents players' relative share of globally efficient contribution level. We find that after controlling for past differences to local and global group averages players react to high shares of globally efficient contributions by lowering their contributions in the subsequent round. In other words, contributions are not driven by global efficiency concerns.

Given the data collected in our four experimental treatments, we reject the role of pure self-interest, global efficiency concerns and motivations based on inequality aversion between various player types in a global group as sole explanations of the observed behavior. In contrast, our analysis shows a clear pattern indicating the importance of locally restricted conditional cooperation determining the nature of voluntary provision strategies to a multilevel public good. In sum, our results suggest that the nature of human behavior in multilevel social dilemma situations can be understood by the coexistence of local conditional cooperation and opportunistic preferences. We find that the observed behavior is strongly driven by asymmetric conditional cooperation relying on local level externalities, leading players to adjust their future behavior to the local conditions. At the same time, the relative importance of positive externalities attenuates over time and the aggregate behavior steadily approaches the opportunistic benchmark condition.

6. Conclusions

The provision of public good regularly embodies interrelated spheres of influence on multiple scales. This paper examines the characteristics of human behavior in multilevel social dilemmas with positive provision externalities to local and global scale. We extend the theoretical analysis of voluntary cooperation mechanisms to intergroup cooperation, largely neglected in the standard models of public good provision. We further show the importance of locally driven conditional cooperation determining the nature of voluntary provisions to a multilevel public good.

Our study of voluntary cooperation with positive externalities on multiple scales may contribute to our understanding of voluntary cooperation within and between asymmetric groups inherent to human social organization. We are confident that the study of multilevel social dilemmas yields relevant insights to decision-making and the incentives to contribute to a common cause when there are potential benefits at multiple scales. However, our findings have arguable limitations due to the stylized nature of experimental investigations. The nature of multilevel public goods provision often involves multiple local groups that may differ in size and cohesion. Single local groups only rarely constitute half of the total population in the global group. These factors among other relevant elements of public goods provision may play important and unexpected roles in human behavior. This opens up a perspective for new research designs that allow studying complementary local and global level provision strategies in various settings that may allow to draw broader implications for real world public policies. At the same time, the study of various governance and communication structures can be extended to constellations where voluntary cooperation provides benefits to individuals at multiple scales.

Our findings may have implications for public policy and organizational thinking. Our data strongly stress the importance of local scale interaction and behavioral inclination to channel voluntary contributions toward the local beneficiaries. First, this suggests that a proper understanding of group identities and other factors defining group boundaries is important when trying to understand the nature of cooperative behavior in human populations. Second, potential policy interventions and institutional arrangements aiming to increase voluntary contributions to a multilevel public good need to acknowledge the regularly prevailing multiplicity of nested reference groups and how individual actors form their social comparison groups in such environments.

Our findings relate to the information processing concerning interdependent outcomes of single decisions at multiple scales. In this context, several potentially important real world implications relate to environmental issues. The issue of locally confined fine particulate pollution and globally diffusing greenhouse gases provide a particularly relevant example of potential information trade-offs in risk communication. Should one emphasize in risk communication and environmental education the more locally confined premature deaths caused by degraded air quality or the likelihood of global consequences of near-term climate change through combustion of fossil fuels? Our findings suggest that individuals are more likely to react to the locally determined consequences of their action. At the same time, we show how the local community members become a natural reference group for social comparisons leading to behavioral adjustments, whereas the past behavior at the global scale has lesser influence on individuals' decisions to contribute to a common cause. In sum, our findings provide strong empirical evidence supporting the potential benefits of building a strong local commitment to encourage the provision of public goods with positive externalities. When drafting institutional responses and determining effective units of governance to promote sustainable provision of multilevel public goods and designing conservation strategies to reserve earth's limited resources, we have to acknowledge the strong local level emphasis of human cooperation.

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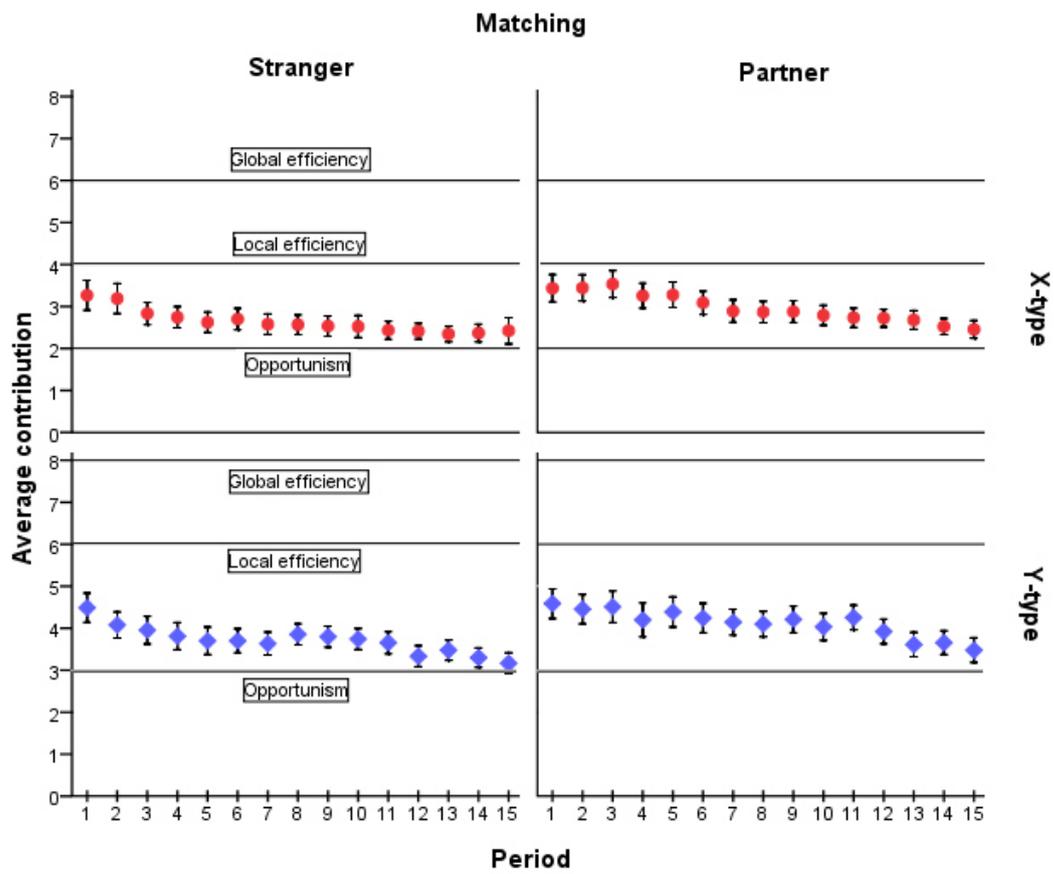


Figure 1: Average contributions to the public good according to the player type over 15 rounds of play in groups with stranger and partner matching.