When the past is present – The ratchet effect in the local commons ⋆

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Abstract

In this paper we investigate the effects of local interaction in a CPR-like environment. We employ a local interaction model where subjects are allocated along a circle and only interact with their most direct neighbors. In traditional social dilemma experiments, the return of one's actions is determined by present behavior while past behavior has no influence on the outcome. Yet, current actions often act as a benchmark for future outcome - the ratchet effect. In situations where dilemmas take the form of a public good, ratcheting implies that it is cheaper to increase public good supply below than above the previous level. Specifically, we argue that the provision of a local public good involves a ratchet effect in production and that the supply varies depending on the distribution of local contributors. Our major observations are the following: (i) Contributions are discouraged under the ratchet effect, and (ii) keeping the marginal return of the public good constant, contributions are higher the larger the relative neighborhood size.

Keywords: Public Goods, Social Dilemma, Experimental Economics, Ratchet Effect, Local Interaction

JEL-classification: C91, D62, H41

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1 Introduction

Empirical research and field studies on the local commons have shown that the anticipated ‘tragedy of the commons’ (Hardin, 1968) does not occur. Although individual maximization of payoffs is in conflict with maintaining the common pool resource (CPR), subjects refrain from destroying it in the end (for an overview see Ostrom, 1990; Ostrom et al., 1994; Hey et al., 2001). Therefore, recent studies on CPRs focus on the appropriation dynamics of renewable resource systems in order to determine the role of institutions for collective outcomes (mostly in small-scale, stateless societies).

A growing body of literature seeks to describe successful local interaction structures for the commons observed in the field. Local interaction is of importance to answer questions like: (i) How do communities manage to live together? (ii) How do societies control individuals’ egoistic and antisocial impulses to refrain from destroying the resource? The field alone can not provide any clear rules or structures to answer these questions. Comparing field and experimental studies, Carpenter (2000) finds that already the formal establishment of a group (definition of group membership) strengthens community cohesion which leads to cooperation.

Blume (1993) and Berninghaus et al. (2002) investigate local interaction effects by assuming each member of a population to be matched with a selected group of population members, called his reference group or neighborhood; groups are supposedly overlapping such that no group or subpopulation can split off from the rest of the population. As a consequence each player directly interacts only with a selected group but indirectly with the whole population. Depending on neighborhood size, it is of importance in a one dimensional interaction structure whether neighborhoods are closed or open (higher cooperation in closed neighborhoods). Yet, cooperation does occur and results converge to the risk-dominant equilibrium.

In contrast to usual CPR situations that apply to a large community of people, the local commons are characterized by the limited pool of beneficiaries. If we think of a small community, the executed task may influence the community as a whole, yet the closest neighbors will have to bear the most direct impact. This might be true for smoking cigars in the public (the more annoying the closer you sit to the person smoking it, as well as for environmental resources, like forests, inshore fisheries, or irrigation systems. Especially for small neighborhoods, when the outcome of the activity is easily (cheaply) observable, local interaction structures are important. Berninghaus et al. (2002) use a coordination game to reveal that subjects play local best reply and individual behavior strongly depends on distribution of neighbors' choices in previous periods. The longer the time horizon and the closer the interaction the more likely subjects cooperate and hence coordinate on the payoff-dominant equilibrium.

For public goods, Blackwell and McKee (2003) show that people contribute more to a local community or neighborhood rather than to a global one. However, actors can be persuaded to overcome the tendency to contribute more to the local public good than to the global public good, when the average per capita return of the latter is rising. In a common view efficient public good provision is negatively related to the number of people in the community due to difficulties in sustaining cooperation in large groups. Experimentally, this question has been addressed, for instance, by Isaac et al. (1994). They find that bigger groups provide the public good more efficiently than small groups, which contradicts the general view that the tendency towards efficient public good provision is negatively related to number of people in the community. Yet, in another study, Isaac and Walker (1988) argue that less contribution in larger groups is solely due to a decreasing marginal return from the public good as the group size increases rather than an effect of pure numbers.

Public good games resemble common pool games in many ways: In CPRs subjects' decisions impose negative externalities on other subjects while contribution to public goods produce positive externalities. In case of a CPR subjects are asked not to appropriate too much from the resource, while for public good provision subjects are asked to contribute for social welfare. Both situations constitute social dilemmas in which individuals must choose between acting in their own interest (defecting) and acting in their group's interest (cooperating). From a theoretical point of view it does not matter whether the dilemma occurs because of taking a public resource for private use or giving part of a private resource for the establishment or maintenance of a public resource.

In our experimental study, we aim to capture the local interaction structure in a CPR dilemma focusing on different neighborhood sizes.[1] This is important for investigating the effects of neighborhood size on social behavior, when provision as well as the willingness to conserve the resource can differ within the whole population. We use a local interaction structure where – like in Berninghaus et al. (2002) – subjects are allocated on a circle. Thus, subjects directly interact with a few group members (the own neighborhood) and indirectly with the group as a whole. Own contribution affects not only the own but also other neighborhoods on the circle. Contrary to Isaac and Walker (1988), who investigate the impact of total group size and marginal return from a public good, our setting allows to compare behavior conditional on the relative neighborhood size, i.e. the size of the neighborhood $|N_m(i)|$ in relation to the population size n, which can be thought of the fraction of neighborhoods of the whole group that are affected by one's own contribution. By comparing predetermined combinations of both parameters, $|N_m(i)|$ and n, we investigate whether a higher impact of own contribution on other individuals results in varying willingness to contribute.

An important feature of common pool resources (i.e. forests, irrigation systems, or fisheries) is that once damaged, they are hardly or even practically impossibly restored. Hence, the natural resource level available in one period crucially depends on the appropriation rate and the natural rate of replenishment. To resemble this scenario in our experiment, we impose a ratchet effect in production, where it is cheaper to produce below than above the previous supply level. For example, heavy deforestation lowers the wood resource. If

[1] For the sake of procedural simplicity, we use a public good game to mimic the basic dilemma situation. Falk et al. (2002) show that findings reported on public goods carry over to common pool problems and vice versa. *'Whereas in a CPR game, subjects' decisions impose negative externalities on other subjects, subjects in a public goods game produce positive externalities. In a CPR game it is nice or kind not to appropriate too much while in a public good game it is kind not to contribute too little to the public good'* (Falk et al., 2002, p. 176) Although one might argue that in experimental studies public goods and common pool dilemmas may create different reference points from which outcomes are evaluated (for a comparison see Polzer et al., 1999), the present study focuses on local interaction rather than on making quantitative statements about the level of contributions /appropriations.

the community decides to afforest again, only small trees are planted that are no perfect substitutes for the previous ones. In the short run it is almost impossible to increase the public good supply up to or above the previous level.

Mostly, experiments on common pool resources or public goods do not capture situations where appropriation or contribution in one period does affect future periods. In a CPR experiment with a non-negligible probability of destruction, Walker and Gardner (1992) actually find that the resource is destroyed in every case causing a significant loss in rents from the resource. Fischer et al. (forthcoming) use an intergenerational common pool resource to investigate exploitation issues on the resource. Although free-riding is predominant, they do not confirm the findings of Walker and Gardner (1992) as in their experiment subjects do have an altruistic restraint and refrain from destroying the resource.

Dillèn and Lundholm (1996) relate the ratchet effect to a contribution mechanism for a public good. Unlike many public goods that are financed through long term contribution schemes (e.g. tax-systems), there are situations in which no such a commitment is made and contribution is set again by the central planner (tax authority) in each period. Hence, it might be that the observed (past) performance acts as a benchmark in fixing the point of departure for next period's contribution level. This resembles a sort of ratchet effect, where future outcome is determined by the current contribution level. [2] In our case of local interaction the absence of a central planner implies that the contribution to the public good can only be observed in the small neighborhood. There is no information available on the level of the local public

[2] For instance, in (municipal) budget plans, the current level of public good production acts as a benchmark for fixing the point of departure for next period's target. Traditionally, the ratchet effect can be observed in principal agent problems where the principal does not have complete information (i.e. in centralized planning of production or government regulation of industries). If the principal does not commit to long term payment schemes, he has to use any information that is revealed by the agent's actions in an attempt to extract the agent's informational rent. In turn this often induces the agent to underproduce to avoid more demanding schedules in the future. (For a detailed discussion of the ratchet principle in dynamic principal agent games see for instance: Freixas et al., 1985; Chaudhuri, 1998).

good for the other neighborhoods. Yet, the outcome of all group members is indirectly related to each other.

The paper is organized as follows: In section 2, we introduce the public good model with the particular ratchet effect and present the theoretical benchmarks for contribution behavior. Further we recall the main research questions we aim to address. Section 3 states the details on the experimental design and procedure. The results are reported in section 4, and section 5 finally concludes the paper.

2 Model and Benchmarks

2.1 The model

Let $P = \{1, ..., n\}$ be the population of $n \geq 2$ individuals who live in 'Circle Town' (see Figure 1) where i's two direct neighbors are $(i-1)$ and $(i+1)$. For each individual $i \in P$ let

$$N_m(i) = \{i-m, i-m+1, .., i, i+1, ..., i+m\} \tag{1}$$

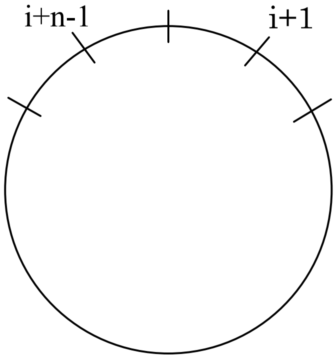
denote i's m-neighborhood, which extends over m neighbors to the right and to the left. For $m = 1$, for instance, $N_1(i)$ includes only i and i's two direct neighbors. All neighbors will be assumed to be symmetric, i.e. the same n-neighborhood applies for all $i \in P$.

The level $y_m(i)$ of public good supply in i's neighborhood depends on the average contribution $\overline{c}_m(i)$:

$$\overline{c}_m(i) = \sum_{j \in N_m(i)} \frac{c_j}{|N_m(i)|} \tag{2}$$

in i's m-neighborhood (where $|N|$ is the cardinality of the set N). Since the ratchet effect implies a dynamic relationship between y(i) and $\overline{c}_m(i)$, we denote for all periods $t = 1, 2, ..., T$ by $y^t_m(i)$ the public good supply and by $\overline{c}^t_m(i)$ the local average contribution in period t. For the sake of simplicity we capture

Fig. 1. The distribution of individuals in Circle Town



the ratchet effect by a piecewise linear dynamic production function of the form

$$
\begin{aligned}
&y_m^t(i) = \beta \min\{\overline{c}_m^t(i), \overline{c}_m^{t-1}(i)\} + \alpha \max\{0, \overline{c}_m^t(i) - \overline{c}_m^{t-1}(i)\} \\
&\text{where } 0 < \tfrac{\alpha}{|N_m(i)|} < \tfrac{\beta}{|N_m(i)|} < 1 < \alpha < \beta
\end{aligned}
\tag{3}
$$

are the usual parameter restrictions for public goods. More specifically,

- $\alpha < \beta$ expresses that it is cheaper to increase $y_m^t(i)$ below rather than above its previous level,
- $\beta < |N_m(i)|$ reflects the usual dominance of no contribution, and
- $1 < \alpha < \beta$ denotes the social efficiency of full contributions.

Individual payoffs $U_i(t)$ are

$$U_i^t = e - c_i^t + y_m^t(i) \;\forall\; i \in \; P \tag{4}$$

where endowment $e > 0$ is constant and the same for all individuals $i \in P$. Since environments can overlap but are never identical, even for direct neighbors, payoffs can vary locally even in the case of equal distributions. Furthermore, payoffs $y_m^t(i)$ are path dependent; a too low level in the past can exclude payoffs, which are yet possible in other neighborhoods with higher previous contributions.

To isolate the impact of the particular ratchet effect on contribution behavior we employ a control treatment, in which public good production does not depend on contribution levels in previous periods. The production technology, given by

$$y_m^t(i) = \beta \overline{c}_m^t(i) \tag{5}$$

is one usually employed in public good games (see Ledyard, 1995, for an overview). All other conditions concerning parameters, such as β, n and m are held constant between experimental and control treatment. By comparing differences in behavior between subjects the particular influence of the ratchet effect can be pointed out.

2.2 The benchmarks

Since even for $\overline{c}_m^{t-1}(i) > \overline{c}_m^t(i)$ the condition

$$\frac{\partial}{\partial c_i^t} U_i^t = \frac{\beta}{|N_m(i)|} - 1 < 0 \tag{6}$$

holds, opportunistic individuals $i \in P$ will always choose $c_i^t = 0$. Actually, $c_i^t = 0$ is the only dominant strategy or, the only strategy that survives repeated elimination of dominated strategies, if we assume the game to be played for finitely many periods. [3]

For efficiency the condition $\beta > \alpha > 1$ implies that

$$\begin{aligned} &\tfrac{\partial}{\partial c_i^t} \textstyle\sum_{j \in N_m(i)} U_i^t = |N_m(i)| \tfrac{\beta}{|N_m(i)|} - 1 = \beta - 1 > 0 \text{ if } \overline{c}_m^{t-1}(i) > \overline{c}_m^t(i) \\ &\text{and} \\ &\tfrac{\partial}{\partial c_i^t} \textstyle\sum_{j \in N_m(i)} U_i^t = |N_m(i)| \tfrac{\alpha}{|N_m(i)|} - 1 = \alpha - 1 > 0 \text{ if } \overline{c}_m^{t-1}(i) < \overline{c}_m^t(i) \end{aligned} \tag{7}$$

[3] If T is the last period, then $c_i^T = 0$ is the only undominated choice in period T. Anticipating $c_i^T = 0$ regardless of the past rounds $c_i^{T-1} = 0$ is the only undominated choice in period $T-1$ etc., which yields $c_i^t = 0$ for $t = 1, ..., T$ and all $i \in P$.

for all $i \in P$. Thus, social efficiency requires full contribution regardless of previous supply levels.

In case of variety in local public good provision and differences in past contributions the incentives for opportunism and/or the socially best of one's neighborhood may be very different for an individual $i \in P$ and his neighbors $j \in N_m(i)$ with $j \neq i$. In spite of their own a-priori-symmetry, differences in past and present contributions can lead to considerable variety of decision problems individuals can encounter. Nevertheless, the asymmetry of local conditions does not question that opportunism dictates non-contribution while neighborhood welfare always requires full contribution.

3 Experimental Design and Procedure

3.1 The Experimental Design

In the experiment the technology parameters $\alpha = 1.1$ and $\beta = 2.2$ are set invariantly. The initial endowment $e = 20$ is provided in each period. Since there is no previous contribution level available in the first period of the ratchet treatment, the production technology from the control treatment is used (see equation 5).

For the neighborhood size parameter m we distinguish $m = 1$, and $m = 2$ and for the total group size $n = 6$ and $n = 12$. Note that even for the small neighborhood $N_1(i)$ with $|N_1(i)| = 3$ the assumption $\frac{\beta}{|N_1(i)|} < 1$ holds what, of course, guarantees also $\frac{\beta}{|N_2(i)|} < 1$ due to $|N_2(i)| = 5$. Thus, we rely on the two–by–two–factorial design displayed in Table 1.

Table 1 reveals different combinations of neighborhood sizes m and population sizes n, henceforth called the *relative neighborhood size (RNS)* $\frac{|N_m(i)|}{n}$: In case of $m = 2$ and $n = 6$, one has $|N_2(i) = 5|$, i.e. the situation where every individual profits from every other but one contribution. Usually public good

Table 1
Relative neighborhood sizes

Neighborhood size m	Population size n	
	6	12
1	$\frac{1}{2}$	$\frac{1}{4}$
2	$\frac{5}{6}$	$\frac{5}{12}$

games capture situations in which the size of the neighborhood equals the population size (see the surveys by Andreoni, 1995; Fischbacher et al., 2001; Ledyard, 1995). For $m = 1, 2$ and $n = 6, 12$ the RNS $\frac{|N_m(i)|}{n}$ can vary from $\frac{1}{4}$ for $(m, n) = (1, 12)$ to $\frac{5}{6}$ for $(2, 6)$ [via the intermediate levels of $\frac{5}{12}$ for $(2, 12)$ and $\frac{1}{2}$ for $(1, 6)$].

Participants repeatedly encounter all four situations indicated in Table 1. However, we do not attempt to conduct a full-factorial comparison of the four different relative neighborhood sizes but rather focus on situations involving equal economic incentives (opportunity costs) of investing in the public good. Note that the marginal per capita return of the public good in the current period is either $\frac{\beta}{|N_m(i)|}$ or $\frac{\alpha}{|N_m(i)|}$, and thus only depending on the neighborhood size determined by m but not on the population size n. Therefore, we compare cooperative behavior in treatment $(m, n) = (1, 6)$ to treatment $(1, 12)$, and contributions in $(m, n) = (2, 6)$ to $(2, 12)$. Since the ratio of the relative neighborhood sizes is the same for both comparisons of treatments [4] we should expect the same pattern of behavioral change between each of the two treatments if relative neighborhood size is crucial. Otherwise, since only population size differs between the two comparisons, behavior might rather condition on population size and thus on marginal per capita return.

Restricting the statistical analysis to the relevant two comparisons of treatments yields an important advantage: We can conduct within-subject comparisons without the need to control for all eight possible orders in which the single treatments are encountered. Instead, we investigate four different orders of RNS treatment sequences (see Table 2). Each of the four orders is

[4] $\frac{N_1(i)}{6} / \frac{N_1(i)}{12} = 2$ and $\frac{N_2(i)}{6} / \frac{N_2(i)}{12} = 2$

Table 2
Different sequences of relative neighborhood size treatments (m,n)

Order	Phase			
	1	2	3	4
1	(1,6)	(1,12)	(2,6)	(2,12)
2	(1,12)	(1,6)	(2,12)	(2,6)
3	(2,6)	(2,12)	(1,6)	(1,12)
4	(2,12)	(1,12)	(1,12)	(1,6)

encountered by two matching groups of 12 participants in both the ratchet and the control treatment, resulting in a total of 192 participants, 96 subjects (8 independent observations) for each technology.

3.2 Research Agenda

In our study, we aim to investigate the effects of local interaction combined with a path–dependent payoff structure (the ratchet effect). To summarize the research agenda, we address the following questions: First, how do subjects react to a ratchet effect in public good production, that makes an increase of the supply above the past level more costly than below this level? We try to answer this question by comparing contribution behavior in the control treatment, where the current level of the public good supply is not path-dependent, to the experimental treatment with the ratchet effect. To the best of our knowledge, no previous experimental study on voluntary public good provision has explicitly touched this issue.

Second, does a variation of the relative importance of one's contribution to the welfare of the population change behavior, even when individual economic incentives are unaltered? Since in our design, each pair of RNS $\frac{|N_m(i)|}{n}$ we compare provides the same marginal return from the public good, we are able to disentangle the effect of RNS from pure group size effects. The effects of group size have been already comprehensively studied in economic literature (e.g. Isaac and Walker, 1988; Isaac et al., 1994; Hindriks and Pancs, 2002).

Most studies confirm the so-called 'Olson-conjecture' (Olson, 1965) that in large groups, compared to small groups or communities, free riding is encouraged and hence the public good is less efficiently provided.

In line with previous findings on the effects of group size and public good provision, one could expect that the willingness to cooperate within a community is higher, when the proportion of the population directly affected by one's behavior is *small* and thus interaction is rather local (as shown by Blackwell and McKee, 2003). However, a similar argument can be made for large RNS: Individuals might feel more responsible for the community's welfare when interaction is rather global, implying that own behavior has direct impact on a large proportion of the community. Thus, we refrain from forming a directed hypothesis, but instead rely on an explorative analysis.

3.3 The Experimental Procedure

The experiment was conducted using z-tree (Fischbacher, 1999) in the experimental labs at the Max Planck Institute for Research into Economic Systems in Jena (May 2002) and at the University of Innsbruck (November 2002 and April 2003). Overall, 192 undergraduate students from various disciplines, aging from 19 to 28 years, participated in the experiment, 99 of them males and 93 females. The sessions lasted between 60 and 80 minutes. Average earnings per subject amounted to about 16 Euros.

On arrival, subjects were randomly assigned into matching groups of 12 members, that remained constant for the whole experiment. The actual constitution of groups was not known to participants throughout the experiment. After reading the instructions and answering control questions[5] which were checked by the experimenters privately, the experiment started. The different experimental orders can be seen in Table 2, i.e. for order 1: $(m, n) = (1, 6)$, every subject was located on a circle consisting of 6 subjects and benefitted from public good production of a neighborhood consisting of three people (including themselves).

[5] Instructions and control questions are obtainable from the authors upon request.

An endowment of 20 tokens was obtained in each period and could be either put into a private account or into a public account. After the decision on contribution, the average contribution of one's neighborhood in the current period was displayed. In order to keep feedback constant between the ratchet and the control treatment, current average neighborhood contribution was shown together with the average neighborhood contribution in the previous period, starting in period 2. Final to each period, the total earnings of this period were displayed. Each of the four orders (combinations of m and n) was played repeatedly for 15 periods, hence the experiment consisted of 60 periods.

4 Results

In the following we report the results we obtained from our experimental study. The results can be classified into two major groups: (i) technology differences, i.e. between control and ratchet treatment, and (ii) findings from changes in the local interaction structure (neighborhood size differences).

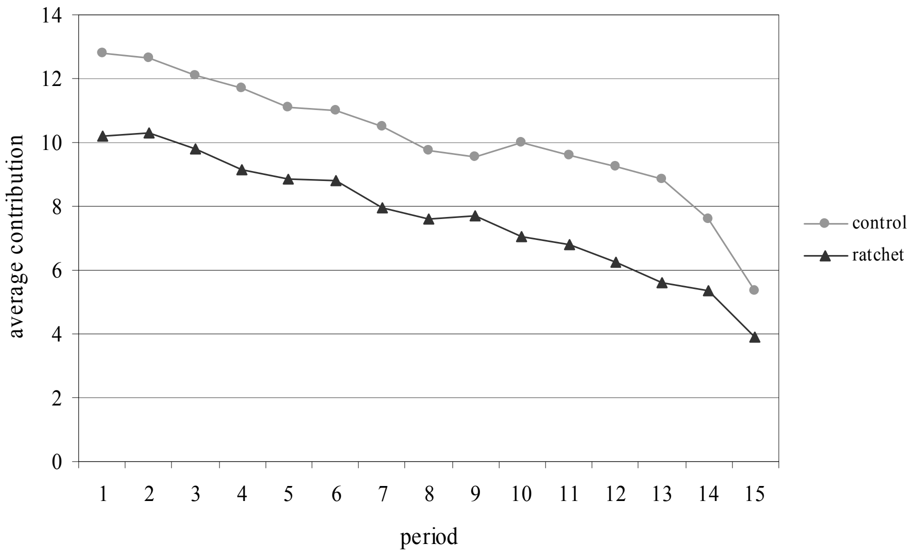
Subjects do not manage to avert the downshifting process implied by the ratchet effect in public good production. Average contributions aggregated over relative neighborhood size treatments are depicted in Figure 2. In every period average contributions in the ratchet treatment are below the contributions in the control treatment.

Observation 1 *If the public good is production is characterized by a ratchet effect, contributions are lower than with a usual linear production technology.*

The differences in averages between the ratchet and the control treatment are statistically significant ($M_C = 10.09, SD_C = 3.00; M_R = 7.67, SD_R = 2.35, z = 3.28, p < .01$; Mann-Whitney-U test).[6] While contributions are already lower for the ratchet treatment in the very beginning, comparing the dynamics of contributions over time by calculating a decay index[7] for each

[6] Analysis on aggregate data is always based on matching group averages.
[7] The decay index refers to the percentage decrease of individual contributions during the 15 periods.

Fig. 2. Average contributions with ratchet and control technology aggregated over all relative neighborhood size treatments



treatment does not reveal any significant differences.

In our within-subjects design, subjects subsequently encounter all four RNS treatments. Although the design is counterbalanced in treatments with respect to the comparisons we undertake, we first assess the order-of-play effects of the different relative neighborhood size treatments. In Table 3, mean contributions and standard deviations are displayed for each of the four possible orders of treatments experienced by subjects as well as the two different technologies. Testing for differences between the RNS treatments, average contributions differ in five out of eight orders depending on when the particular treatment was encountered in the sequence of game (Kruskal-Wallis-Tests based on individual averages). In consideration of this evidence, subsequent statistical analysis is applied to individual data for each order, separately, in addition to the analysis of data aggregated over orders-of-play for each treatment.

Retesting both technology treatments separately for each relative neighborhood size and each order, significantly higher contributions in the control treatment than in the ratchet treatment can be confirmed for 7 out of 16

Table 3
Mean contributions (standard deviations) in the four different relative neighborhood size treatments, separately for both production technologies

Relative Neighborhood Size	Order				Kruskal Wallis	
control	1	2	3	4	$\chi^2_{df=3}$	p
(1,6)	12.9 (3.9)	11.4 (5.2)	9.9 (6.4)	10.5 (3.6)	5.0	.17
(1,12)	11.7 (5.0)	11.3 (5.3)	8.1 (6.2)	8.1 (3.8)	9.1	.03*
(2,6)	9.9 (5.0)	12.5 (5.6)	9.3 (5.6)	8.9 (5.2)	6.6	.09
(2,12)	9.0 (3.9)	8.8 (4.0)	8.9 (4.9)	10.3 (4.3)	2.1	.56
ratchet	1	2	3	4		
(1,6)	11.6 (4.6)	9.4 (3.5)	8.8 (5.2)	5.3 (3.7)	23.4	.00**
(1,12)	8.3 (4.8)	6.6 (2.0)	6.9 (5.1)	4.1 (2.9)	15.4	.00**
(2,6)	6.2 (3.4)	10.8 (2.8)	10.9 (5.0)	6.7 (3.7)	24.7	.00**
(2,12)	5.3 (3.9)	7.6 (2.7)	8.3 (4.8)	5.8 (2.9)	9.3	.03*

Note: ** denotes significance at the 1 % level, * at the 5 % level.

possible cases (see Table 4).[8]

Table 4
Results of Mann-Whitney U-Tests
Tests between ratchet and control technology for each relative neighborhood size treatment and each order (z-values with p-values in parentheses)

Relative Neighborhood	Order			
Size	1	2	3	4
(1,6)	1.27 (.21)	1.46 (.14)	.63 (.53)	4.02 (.00)**
(1,12)	2.22 (.03)*	3.42 (.00)**	.52 (.61)	3.50 (.00)**
(2,6)	2.65 (.01)**	1.70 (.09)	1.11 (.27)	1.4 (.16)
(2,12)	2.92 (.00)**	1.25 (.21)	.62 (.54)	3.6 (.00)**

Note: ** denotes significance at the 1 % level, * at the 5 % level.

Although average contributions differ with respect to the order in which the

[8] Tests applied separately for data in each order and treatment based on individual data.

RNS treatments are encountered, the relation between treatments to compare is unaltered: Regardless of the order-of-play, contributions are almost always higher in the environment with larger RNS (or more global interaction); i.e. participants' contributions are higher in (1,6) than in (1,12), and in (2,6) than in (2,12), even though the marginal return of the public good remains constant [see Table 3 for the pairwise comparisons of relative neighborhood size treatments (1,6) to (1,12) and (2,6) to (2,12)].

Figures 3 and 4 give an impression of average contributions in the different neighborhood size treatments aggregated over the four orders of play, but separately for the two technologies. Since the neighborhood is the actual relevant reference group for public good production, it is expected that behavior does not differ among treatments with constant neighborhood size. However, it is noteworthy that – at least in the ratchet treatment – behavior in the same population size, i.e. $(1,6)$ and $(2,6)$ or $(1,12)$ and $(2,12)$, shows closer resemblance than behavior in the same neighborhood size.

Observation 2 *Keeping the marginal return of the public good constant, contributions are higher in a larger relative neighborhood than in a smaller one.*

This observation is supported by Wilcoxon Signed Ranks Tests on the aggregate group level comparing treatment (1,6) to (1,12) and (2,6) to (2,12) with data pooled over orders-of-play, as well as on the individual level separately for each order. [9] Table 5 displays mean contributions and standard deviations as well as the results of statistical testing. Overall, cooperation is higher in the larger relative neighborhood sizes (1,6) and (2,6) compared to the smaller ones. This pattern is confirmed applying tests to each order: Contributions in treatment (1,6) are always significantly higher than in (1,12) in each order; similarly, contributions in (2,6) are nearly always higher than in (2,12), expect for order 4, where no significant differences can be detected, and order 1, where a difference can only be confirmed on a 10 % margin of error. Figure 5 gives a more detailed illustration of behavior of groups in different orders. Generally, the results show that cooperation is higher when interaction is rather global

[9] As Figure 3 and Figure 4 give no indication of dissimilar patterns concerning contributions in different relative neighborhood sizes for both technologies, we do not differentiate between technologies in this analysis.

Fig. 3. Average contributions in the four relative neighborhood size treatments (control treatment)

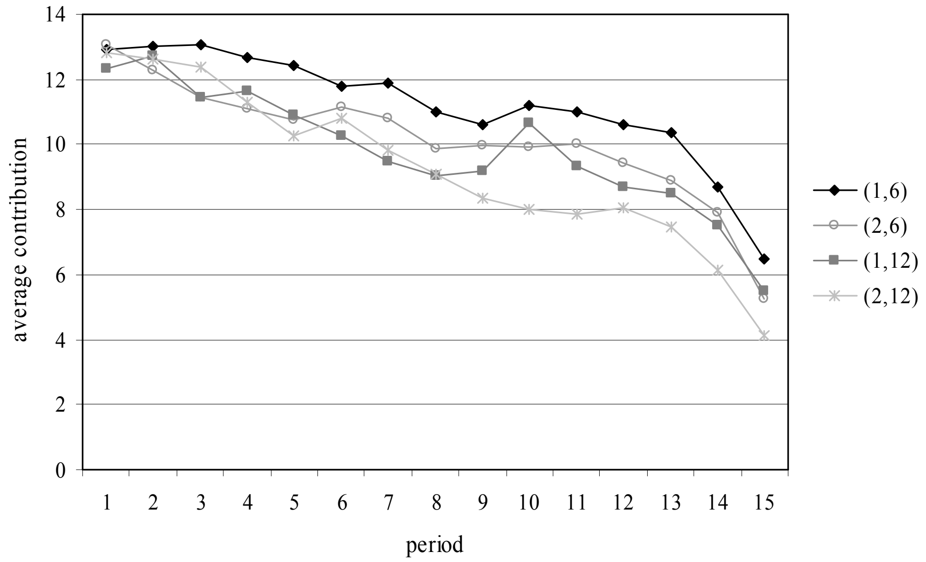


Fig. 4. Average contributions in the four relative neighborhood size treatments (ratchet treatment)

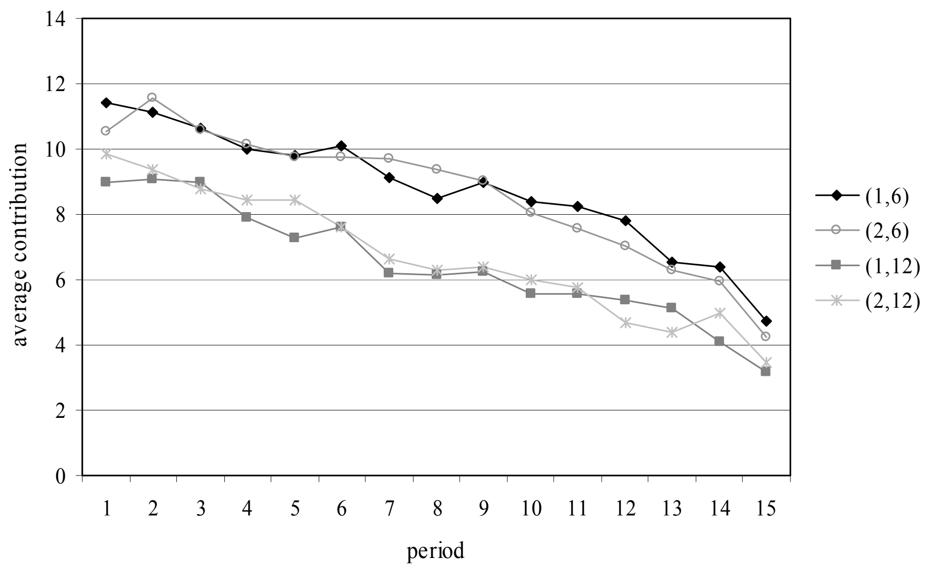


Fig. 5. Average contributions in the four relative neighborhood size treatments per order (two groups each)

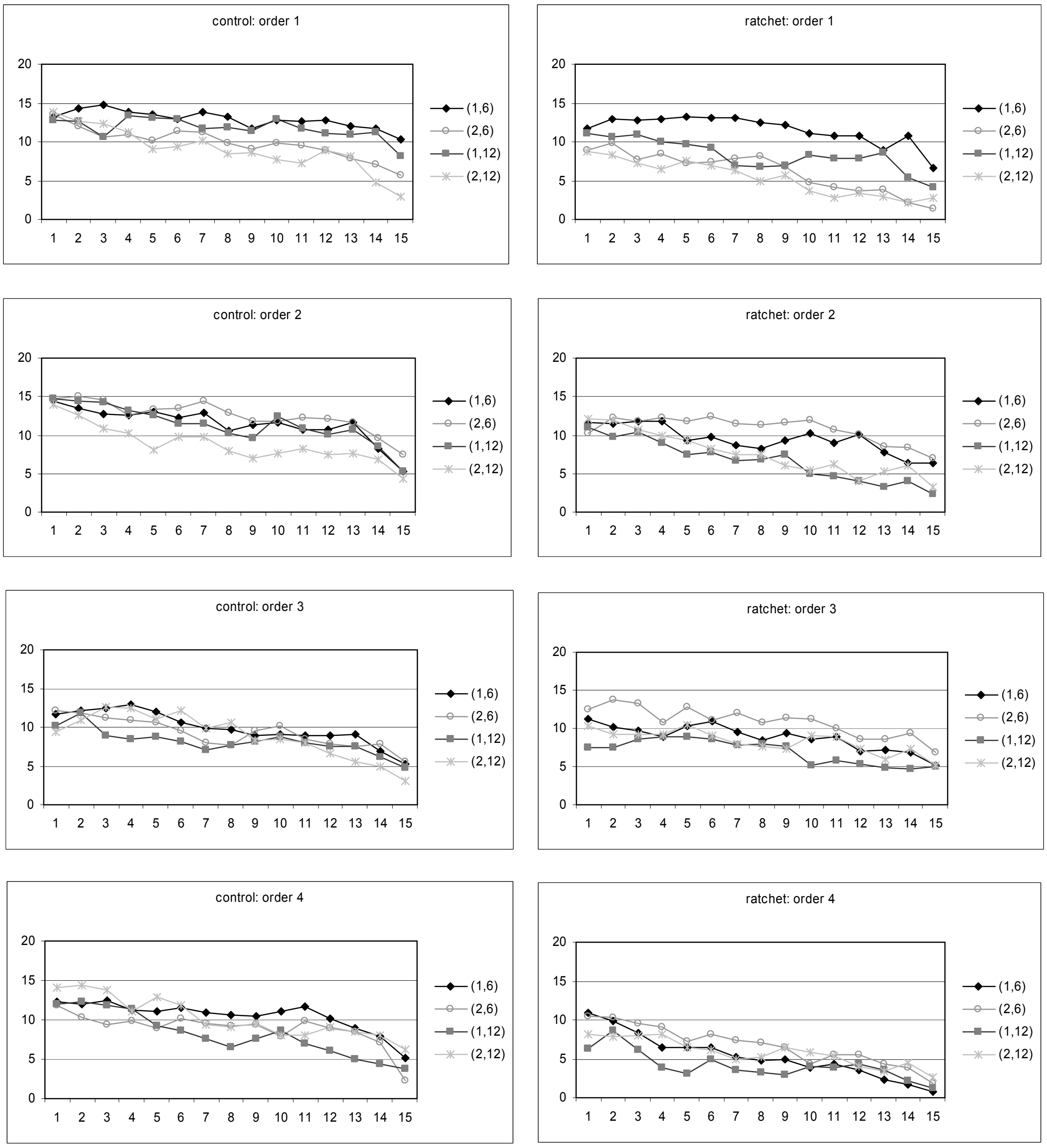


Table 5
Mean contributions (standard deviations) in the four different relative neighborhood size treatments, and relevant pairwise comparisons of treatments

Order	Relative Neighborhood Size		Wilcoxon Signed Ranks	
	(1,6)	(1,12)	z	p (2-tailed)
overall	9.9 (3.1)	8.2 (3.2)	3.46	.00**
1	12.2 (4.3)	10.0 (5.2)	3.71	.00**
2	10.4 (4.5)	8.9 (4.6)	3.01	.00**
3	9.4 (5.8)	7.5 (5.7)	4.28	.00**
4	7.9 (4.5)	6.1 (3.9)	3.59	.01**
	(2,6)	(2,12)	z	p (2-tailed)
overall	9.4 (2.9)	8.0 (2.1)	2.43	.02*
1	8.0 (4.6)	7.2 (4.3)	1.89	.06
2	11.6 (4.5)	8.2 (3.5)	5.42	.00**
3	10.1 (5.3)	8.6 (4.8)	3.03	.00**
4	7.8 (4.6)	8.0 (4.3)	.56	.58

Note: ** denotes significance at the 1% level, * denotes significance at the 5 % level.

than local, i.e. the impact of the individual contribution on the welfare of the community is high.

We estimate a panel regression model with matching groups as cross-sections to further validate our results. The following variables are taken into account: period (1 to 15), phase (1 to 4), technology of public good production (0=control, 1=ratchet), order-of-play (1 to 4), relative neighborhood sizes (1=$\frac{1}{4}$ corresponding to treatment (1,12), 2=$\frac{5}{12}$ corresponding to ((2,12), 3=$\frac{1}{2}$ corresponding to (1,6) and 4=$\frac{5}{6}$ corresponding to (2,6)). The results of the original model indicate an autoregressive process, which was accounted for in the presented results (autoregressive term to the lag one). Evidence obtained by non-parametric testing of average contributions is corroborated and illustrated in more detail (see Table 6): Contributions decline over time within each sequence, but do not significantly decrease over phases. Contributions are lower with ratchet production technology and increase in the relative neighborhood

Table 6
Panel least squares regression on contributions

Dependent variable: contribution
Method: General Least Squares (Cross Section Weights)
White Heteroscedasticity-consistent standard errors and covariance
Number of cross sections used: 16
Total panel (balanced) observations: 944

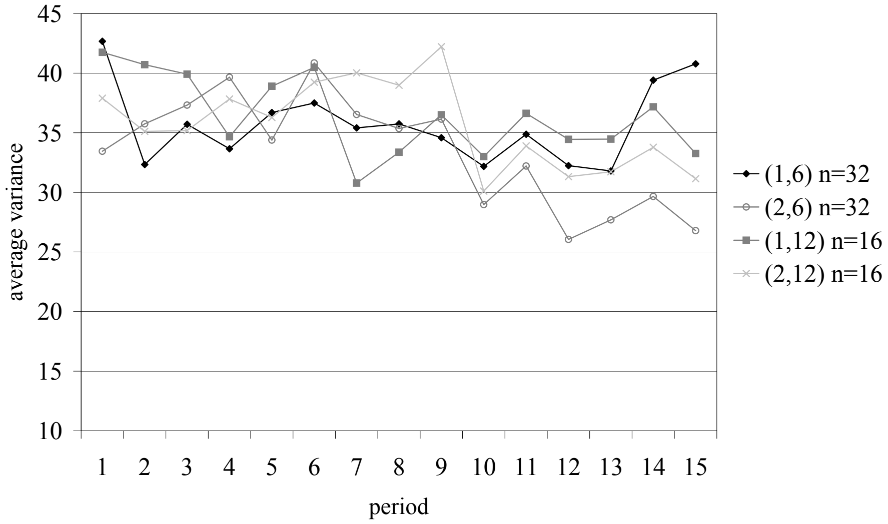
Variable	Coefficient	Std. Error	t-Statistic	p
Constant	15.397	1.381	11.15	0.000**
Period	-0.490	0.027	-18.32	0.000**
Phase	-0.455	0.276	-1.65	0.099
Technology	-2.116	0.660	-3.21	0.001**
Order	-0.716	0.302	-2.37	0.018*
Relative neighborhood size	0.561	0.161	3.49	0.001**
AR(1)	0.856	0.018	48.37	0.000**
Weighted Statistics				
R^2	0.8285	Mean dependent variable		8.9579
Adjusted R^2	0.8274	S.D. dependent variable		3.7108
S.E. of regression	1.5415	Sum squared residuals		2226.7
Log likelihood	-1723.7	F-statistics		754.52
Durbin Watson stat.	2.2087	p(F-stat.)		0.0000

Note: * denotes significance at the 5% level, and ** denotes significance at the 1% level.

size. Furthermore, current contributions are largely dependent on behavior in the previous period and differ among orders-of-play.

Evidence suggests that even when marginal return of contributing to the public good is constant, individuals are more cooperative when direct interaction involves a large area of the community rather than a small one. Therefore, the relative impact of one's contribution on the community is crucial for the level of cooperation sustained. To further investigate the importance of the interaction structure, we look at the dispersion of average contributions between neighborhoods. Figure 6 displays the standard deviation of average neighborhood contributions over time for the four relative neighborhood size treatments. On statistical grounds, the dispersion of average neighborhood

Fig. 6. Average variance of contributions in the four relative neighborhood size treatments



contributions should not considerably differ among communities of the same size and the same number of neighborhoods, respectively.

Observation 3 *Contributions are, on average, less dispersed in larger relative neighborhood sizes, i.e. when interaction is rather global than local.*

The average variances of contributions diverge over time among the different RNS treatments (see Figure 6 [10]). Applying the F-test for homogeneity to compare the average dispersion of contributions aggregated over time reveals that contributions are significantly less dispersed in the treatments with larger relative neighborhood size, i.e. the average variance is higher in treatment $(1,12)$ than in $(1,6)$ ($F_{(15,31)} = 2.04, p < .05$), and in $(2,12)$ than in $(2,6)$ ($F_{(15,31)} = 2.14, p < .05$). Although, on statistical grounds, contributions might be expected to be more dispersed in smaller samples, our findings indicate the opposite: average dispersion is lower in the smaller populations, i.e. when interaction is rather global than local. One might interpret this result as follows: the smaller the neighborhood share on the total population, the higher the direct impact of ones' contribution to the outcome. Hence, the contributor

[10] As in treatments (1,6) and (2,6) there are 32 populations (circles) in total and in treatments (1,12) and (2,12) there are 16 populations (circles), the levels of variance are not straightforwardly comparable. However, in the subsequent statistical analysis, the difference in sample size is accounted for.

sends direct signals to the other contributors. When the neighborhood share on the total population is rather large, the lower the direct impact of a contribution. The results go inline with Blackwell and McKee (2003), who find that in the presence of global and local public goods, subjects rather contribute to local public goods.

5 Discussion and Conclusion

Current literature on the dynamics of local commons or public goods describes the interaction structures appropriators and contributors undertake to avoid the ruination of the resource, respectively to guarantee the provision of the public good. To explain the behavior of the subjects, it is important to understand how institutional agreements are made and how influential interaction structure is. Although observations from small groups can only act as a rough estimate to understand how institutions are formed in large groups, the functioning of the first is inevitable for the performance of the latter.

In our experiment on local public goods, we aim to capture the interaction structure in a CPR dilemma focusing on different relative neighborhood sizes (RNS). Subjects interact with group members allocated along a circle. The design reflects a small neighborhood where the outcome of one subject is affected not only by his decision but by the decision of all other affiliated group members. Given the interaction structure we use in this experiment own contribution has a direct impact on the outcome of the own neighborhood, while the outcome of the other group members is affected only indirectly. This might be true for situations where villagers collect fire wood or mushrooms from a nearby forest as well as for bargaining for free up- or download capacities in a P2P-network (although here subjects are rather allocated randomly than on a circle).

Although we confirm the 'Olson-conjecture', i.e. contributions to neighborhoods in large groups ($n = 12$) are smaller than to neighborhoods in small groups ($n = 6$), we are able to add some important new insights. Previous findings on the effects of group size in the voluntary provision of public goods reject a pure number effect, meaning that less cooperation in large groups is only due to a response to the change of incentives, i.e. the marginal per capita return (see Isaac and Walker, 1988; Isaac et al., 1994). We find that – while holding the relevant neighborhood size and thus marginal returns from the public good constant – contributions are higher the more global the interaction is. In other words, the higher the proportion of people in the community who are directly affected by the own action the higher the level of sustainable cooperation. Hence, it seems that if the neighborhood makes up a relatively large share of the community, subjects are willing to take over more responsibility for the community as a whole. Blackwell and McKee (2003) find that subjects who prefer to contribute to a local public good however can be convinced to likewise contribute to a global public good if the marginal return of the latter rises. Given the right incentives, i.e. constant marginal return regardless of group size, increases in RNS have positive effects on cooperation. In our setting, larger relative neighborhood sizes seem to encourage the contribution behavior. This observation might be strengthened by the fact that the dispersion of average contributions of neighborhoods in the community is higher the smaller the RNS, i.e. when direct interaction is restricted to a smaller division of the community.

For the traditional commons, i.e. ecosystems, there is no doubt that present over-appropriation reduces the future capacity of the common pool. Moreover, current behavior mostly affects future outcomes as subjects take the present as focal point for the future. Therefore, we introduce a ratchet effect in our experimental design. In this first step, the ratchet effect only relates to the previous period and does not take a longer time horizon into account. Our prototypical experiment is, however, especially designed to allow several variations in later studies.

Compared to results from standard public good games with a time independent path of production we find that contributions are discouraged under the ratchet effect. Yet, ratcheting only effects the level of contribution and not the pattern of interaction itself. In presence of a ratchet effect in production subjects prefer to invest more into their private account than to the public account. Differences are already present in the first period (without the ratchet effect) and carry on over all periods, however with less impact in the later periods.

In the present study, we introduce a ratchet effect into public good production to capture the effects of path dependency. Observations from the field indicate the importance of present decisions for future outcomes of social dilemma situations. Furthermore, interaction structures in communities are strongly determined by the exchange within the different neighborhoods of a specific community. In the experiment we can only stylize the interaction structures observed in the field. Nevertheless, we are able to test which settings are more likely to encourage cooperation while keeping constant individual incentives. Although the investigation of both topics is rather explorative, the stylized facts found may serve as an starting point for a more systematic variation of the process of path dependency and different interaction settings.

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