CPR provision close to the social optimum despite unequal appropriation -
Experimental evidence from Pakistan

Aneeque Javaid, Thomas Falk

Abstract

Irrigation systems are a special case of common-pool resources (CPR) where some users have preferential access to resource exploitation due to their advantageous location. This potentially aggravates collective-action challenges associated with common-pool resources such as the under-provision of necessary infrastructure as a result of unequal appropriation of water resources. From the point of view of standard economic theory, this inherent asymmetry results in more complexity which decreases the chances of successful self-governance.

In contrast to theory, empirical evidence from around the world challenges such pessimism towards decentralized governance of irrigation system. Many communities have devised various institutions to overcome these problems.

We employ field experiments based on the experimental design of Janssen et al. (2011) to analyse the effectiveness of different institutional settings (communication, traditional authority and external sanctions) in establishing and maintaining a stable and fair CPR management system under conditions of asymmetric access to the resource base. The experiments were carried out in eight villages in Punjab/Pakistan with 176 farmers.

In the experiments, Punjabi farmers managed to provide the CPR at a level close to the social optimum even without communication or enforcement opportunities. The equal investment in water infrastructure seems to be a strong intrinsic social norm even though those in disadvantageous positions (tail-users) earn less than those who have preferential access (head-users). Introducing institutions as treatments, disadvantaged players (tail-users) of groups being allowed to either directly communicate or to call on a traditional authority further enhanced average earnings. In contrast, groups having the option to fine fellow players did not improve their performance and therefore had significantly lower average earnings. Only traditional authority groups managed to improve the overall group welfare with the introduction of the institution.

Keywords: Field experiments, Common pool resources, Asymmetric access, Irrigation management, Traditional authorities

1 Introduction

Predictable and consistent supply of water plays a huge role in agricultural production. Irrigation tends to serve that purpose in areas where either there are very little fresh water resources or where the availability of water depends on seasonal fluctuations. In an historical context the transition from agricultural society to industrial one depended largely upon the surplus food generated by the extensive and better use of irrigation systems and techniques (Childe 1946). According to Gleick (2000) irrigated land has increased from 50 to 267 million hectares in the 20th century, with much of this increase taking place in developing countries.

Agriculture remains an integral part of Pakistan´s society as well as its economy accounting for about 25% of the GDP (World Bank 2005). However most of Pakistan's land area is arid or semi-arid and requires consistent water supply for agriculture to be viable (World Bank 2004). Irrigation has played a crucial role in managing water supply. Agriculture generally consumes more than 90% of the country's fresh water resources (World Bank 2005). Traditionally, a network of inundation canals stemming from Indus river system was used to fulfill this need (Badruddin 1993). Nevertheless, due to the fact that inflow in this system is mainly derived snow and glacier melt as well as seasonal rainfall in the recharging catchment areas, water supply is seasonal and highly variable. The British colonial era marked the beginning of constructing the required infrastructure for controlled year round irrigation. This process was completed in 1962 when all traditional canals have been connected to a centralized system (Badruddin 1993). As a result Pakistan has one of the largest irrigation systems in the world. The total irrigated area in Pakistan is about 20.80 million hectares and belongs almost exclusively to the Indus river system (World Bank 2005). About 90% of the country's agricultural output comes from these irrigated areas (World Bank 2005).

Many irrigation systems especially in developing countries show characteristics of common pool resources and are managed as common property. Often a group is jointly maintaining infrastructure and the investment by an individual generates positive externalities for the whole group. Standard economic theory predicts that this leads to free-rider problem and as a consequence there is under-investment in resource provision (Olson 1964). Secondly, participants in irrigation systems have to be aware of potential negative externality caused by an individual user's water extraction (Gordon, 1954; Scott, 1955; Hardin, 1968). In addition, irrigation systems represent a somewhat unique problem of preferential access to the resource for some users. The problem of asymmetric access arises due to the fact that most surface irrigation systems are uni-directional i.e. water flows from one end to the other. Users who are located closer to the physical infrastructure (head-users) enjoy preferential access to water as compared to those users who are located further away from the physical infrastructure (tail-users). Although asymmetric access problem could practically occur for many different types of common-pool resources, it is a distinctive feature of irrigation systems.

The challenges associated with asymmetric access are well known amongst policy makers and communities in our study area. As an approach to address this problem a rotation in water access known as *Warabandi*[1] was and is used by the local farmers. In this system each participant gets preferential access to water based on a rotational schedule. Farmer-establihed rotations are called *kachcha* (meaning impermanent) and cannot be legally enforced. Inspired by the communities' indigenous knowledge the Irrigation Department establihed similar systems under its own rules which are called *pakka*, meaning solid, legal, regulated, or formal (Merrey et al. 1986). Up until the 1980´s both these institutional set-ups were prevalent in the Punjab region. Nevertheless, due to increasing conflicts and growing dissatisfaction with the influence of local leaders, *kachcha warabandi* was gradually replaced by *pakka warabandi* all over the region (Hassan, Hamid, and Bandaragoda, 1998). At present at least theoretically the schedule is fixed and allocation of water takes place according to pre-determined formulas. In practice, rules are inconsequently enforced and there are complaints about rent seeking by government agents and their (perceived) unfair and corrupt behavior (Bandaragoda and Saeed ur Rehman, 1995).

In theory different institutional mechanisms can solve asymmetric access challenges. Proponents of state regulations argue that effective development and management of irrigation systems necessitate a central authority (Wittfogel, 1981[1957]). As an alternative, horizontal coordination on the basis of well-defined property rights can provide incentives for welfare maximizing infrastructure investments and extraction (Welch, 1983). In such a case marketable shares of water flow provide farmers with incentives to trade in such a way that water is diverted to the most productive users (Hartman & Seastone 1970; Howe et al. 1986). Both of these points of views implicitly assume that communities which share these resources do not have the necessary ability or incentives to overcome these challenges on their own. This assumption is not backed up by empirical evidence. A large number of case-studies in both developed and developing countries show that many communities have been quite successful in managing common pool resources with asymmetric acess (see for example Hunt 1988; Tang 1989; Coward and Levine, 1987; Fleuret, 1985; Bardhan, 2000; Sarker and Itoh, 2001, Trawick, 2001; Bravo, Giangiacomo, and Marelli, 2009).

Similarly experimental studies show that the predictions of standard economic theory are invariably not consistent with the behavior shown by participants in experimental settings. One key finding is that the average contribution in the initial stages of voluntary contribution mechanisms or public-good games is generally observed to be around 50-70 percent of each player's total endowment

[1] Literally it refers to the list of rotational turns or times when each shareholder in a watercourse obtains his water supply (Bandaragoda and Saeed ur Rehman, 1995).

(Ledyard 1995). Similarly many other studies employ common pool resource games to show that over-extraction by resource users is not an inevitable outcome. The level of cooperation is often maintained or even enhanced by the presence of opportunities to communicate (Balliet 2010) and/or to sanction other players (Fehr and Gächter 2000).

Nevertheless, this line of research is characterized by two major shortcomings with regards to their relevance for irrigation systems in particular. First, most of these studies have symmetric game structure, and asymmetries in many dimensions are not addressed (Murnighan et al. 1990). Secondly, most of these studies are conducted with university students from developed countries who do not have any particular experience with problems related to irrigation systems.

Given this background we decided to study the behavior of irrigation farmers in Pakistan belonging to communities who have been involved in a publicly managed irrigation system for a long period of time. We want to learn about the capacity of communities to collectively manage resources.

The overall focus is on three broad questions:

a) To what extent can community members solve appropriation and provision problems of irrigation systems without resorting to any outside interference?

b) How affects asymmetric access individual provision and appropriation decisions?

c) How affect institutional interventions individual provision and appropriation decisions?

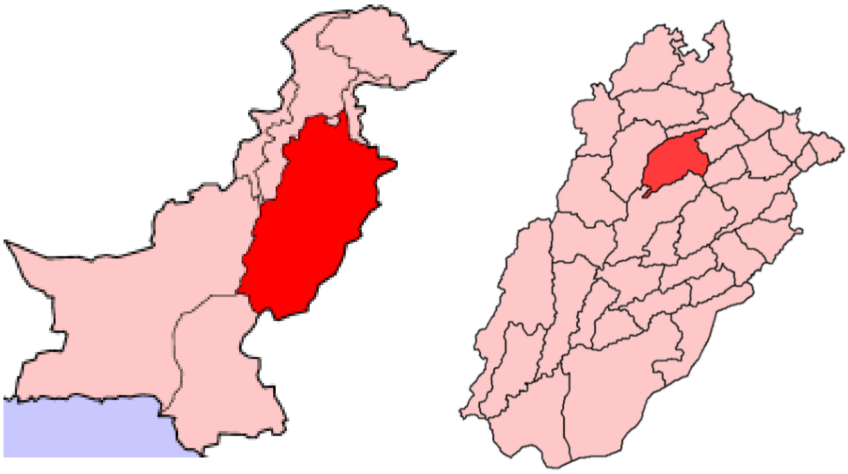
We apply an experimental design to address these questions. Our experiment design is based on Janssen et al. (2011) which incorporates the problem of asymmetric access. We look at the problems of provision to and appropriation of collective resources framing the setting as an irrigation game. Our experiments were carried out in villages of Punjab, Pakistan that heavily rely on irrigation. Farmers who participated in the game frequently deal with the collective action problems related to irrigation in their everyday life. Due to the fact that the experiments were conducted with sample population who deal with the underlying problems in their daily life, our experiments can be classified as artefactual field experiments (Harrison and List, 2004). We introduce different institutional treatments in the experiment in order to test their effectiveness to improve cooperation and group well-fare.

2 Background and sample selection

The research was carried out in the Sargodha district in the Punjab region of Pakistan (Figure 1). Punjab has an old and one of the most extensive irrigation systems in the world. The strong agriculture sector produces in particular wheat, rice, and sugarcane. Sargodha is well-known for its fruit orchards.

The district of Sargodha is situated in the central center-western plains of the Punjab, Pakistan between the Jhelum and Chenab rivers. The growth of population was strongly linked to the construction of an extensive network of canals for irrigation purposes during the British colonial era (Ouseley and Davies 1866 cited in Cheema et al. 2009 and Wace 1933). In effect this area was developed as a part of larger Lower Jhelum Canal Colony ("LJC") scheme by providing adequate water supply to create agricultural output but also resulting in large scale internal migration (Ali 1979, 1988).

Figure 1: (a) Location of Punjab in Pakistan. (b)Location of Sargodha district in Punjab (source: Government of Sargodha)



Historically the area was managed centrally using the unique institutional structure of *lambardar*[2] and *patwari*[3] during British colonial era. After independence the Government of Pakistan basically continued with the same institutional structure. Only in the late 1990s' it became evident that the prevalent management structure was unsustainable and inefficient as revenue collection from water taxes[4] fell from 79 percent during 1993/94 season to 56 percent at the end of 2000/01 season[5]. Escalating conflicts related to water management in combination with an increasing reluctance to provide funds and labor to the maintenance work resulted in a quick deterioration of water canals as well as other irrigation infrastructure and uncoordinated and unfair distribution of water resources among different farmers (both tail and head-users). The Government of Punjab reacted by introducing a more participatory approach towards irrigation management in which the rights and duties regarding irrigation infrastructure were (partly) transferred to user organizations (such as Farmer organizations and *Khal Panchayats*[6]). The new irrigation management is moving away from a semi-government system to a common property regime.

The Sargodha district comprises of 841 villages out of which 8 villages were chosen for experiments. The villages where selected in coordination with agriculture extension staff at places

[2] ***Lambardar*** = a person representing landowners appointed by the revenue department at the village level to collect state revenues and to perform other administrative duties (Shah, Hussain & ur Rehman 2000).
[3] ***Patwari*** = Revenue Department official responsible for keeping land records and assessing as well as collecting abiana (Shah, Hussain & ur Rehman 2000).
[4] ***Abiana*** = Irrigation water charge. Traditionally the assessment was done by Patwari and collection was done by *Lambardar* with the help of Patwari.
[5] The figures quoted are given by the Irrigation Department, Government of Punjab.
[6] ***Panchayat*** = a council of elders representing a village or caste. (http://oregonstate.edu/instruct/anth370/gloss.html#O)

used regularly by field staff for their interaction with farmers. Almost all the participants were in one way or the other closely associated with agriculture and irrigation. Table 1 summarizes socio-economic attributes of the sample population.

Table 1: Socio-economic attributes of the experiment population

Average age				44 years	
Average household size				7.7 people	
Average landholdings				13.0 acres	
Marital Status		**Education level**		**Landholdings (type)**	
Married	77,84%	None	14.77%	Freehold	85.37%
Single	17,05%	Some primary school	9.66%	Leasehold	11.59%
Widowed	5,11%	Primary school	12.50%	No title	3.05%
		Secondary school	50.57%		
		Technical or University	12.50%		
Income sources		**Transport ownership**		**Share cropping**	
Cultivation	85.8%	Car	17.61%	Yes	19.89%
Livestock	60.8%	Motor-cycle	59.09%	No	80.11%
Employment	8.52%	Bicycle	57.39%		
Private business	5.68%	None	8.52%		

The experiment venue was a *dera*, which is a gathering place maintained and owned by wealthy farmers. It is the place where community leaders/elders meet to discuss general matters of concern including water disputes. People were invited to the experiments by Mosque loudspeaker announcements, cell phone messages, and word of mouth.

3 Theoretical foundations associated with collective action problems in irrigation management

Ostrom, Gardner and Walker (1994) divided the problems associated with common pool resources management into two main processes: appropriation and provision. Due to our exclusive focus on irrigation systems we add another aspect, so the three most important problems of collective action in irrigation systems are associated with 1) the provision of the CPR, and 2) the appropriation from the CPR taking into account 3) asymmetric access.

3.1 Provision problem

Olson (1964) argues that public goods would be under-produced in a society of rational human beings due to the fact that it is difficult to exclude anybody from enjoying the goods. The same applies to common pool resources. A rational person would have strong incentive to free-ride and not contribute to the investment in the good. This tendency is stronger when a single person's investment has a minuscule impact on the amount of public or CPR good being produced.

Building and maintaining an irrigation system can lead to the described problem if exclusion from using the system is costly. In systems which are managed by communities the entire responsibility of initial as well as subsequent investments falls on the community members. Even in many large-scale irrigation systems where government provides the capital infrastructure the provision and maintenance of tertiary-level facilities often falls under the domain of communities. This holds true for the case of Pakistan where farmers did not have much say in the management of overall irrigation infrastructure but were involved in tertiary level infrastructure management (Mirza, Hassan and Bandaragoda, 2000).

It is a challenge to develop institutions which provide effective incentives for group members to make their contributions. In this context it is important to be aware that contributions often involve monetary payments and the provision of labor.

3.2 Appropriation problem

The difficulties in the coordination of a group's appropriation from common-pool resources have their origin in the subtractive nature of the good (Ostrom and Gardner 1993). The extraction decision by one user adversely affects the amount of resources available for other users. Overuse of one group member leads to a group well-fare loss as the result of typical concave marginal utility functions. The main concern is to balance social efficiency versus short-term private utility maximization. This is another example for externalities, where an individual's cost of extraction does not take into account the full social costs. Social efficiency would require that each resource unit is distributed to the user who gains the greatest marginal benefit. Nevertheless, a rational user has no incentive to give up appropriation even if her marginal utility from consuming that unit is less than the marginal benefits gained by another user. Even without referring to concepts of efficiency and overall group welfare, concerns about equality and fairness imply the need for coordination between different actors and potential of conflicts. The problem is well reflected in the case of irrigation management (Tang 1989). The benefits from resource utilization are private while costs of over-exploitation are social. The result is an often suboptimal distribution of water extraction.

3.3 Asymmetric access problem

The third aspect of collective action in irrigation system management is the asymmetric access. As a result for instance of physical location, technological advantages, or social norms some resource-users have preferential access to the resources. Irrigation systems provide a clear case of common-pool resource where the problem of asymmetric access plays a critical role. In the case of irrigation systems resource-users who have preferential access to the CPR have incentive to extract water up to the level which maximizes their utility. Due to the scarce and subtractive nature of water resources this means that resource-users with less preferential access have to extract what is left for them. As a result disadvantaged users have low incentives to contribute to investments in the infrastructure. This often leads to under-provision of the CPR especially in cases when the preferential users do not have the capacity to maintain the infrastructure on their own (Ostrom and Gardner 1993).

3.4 Experiment Design

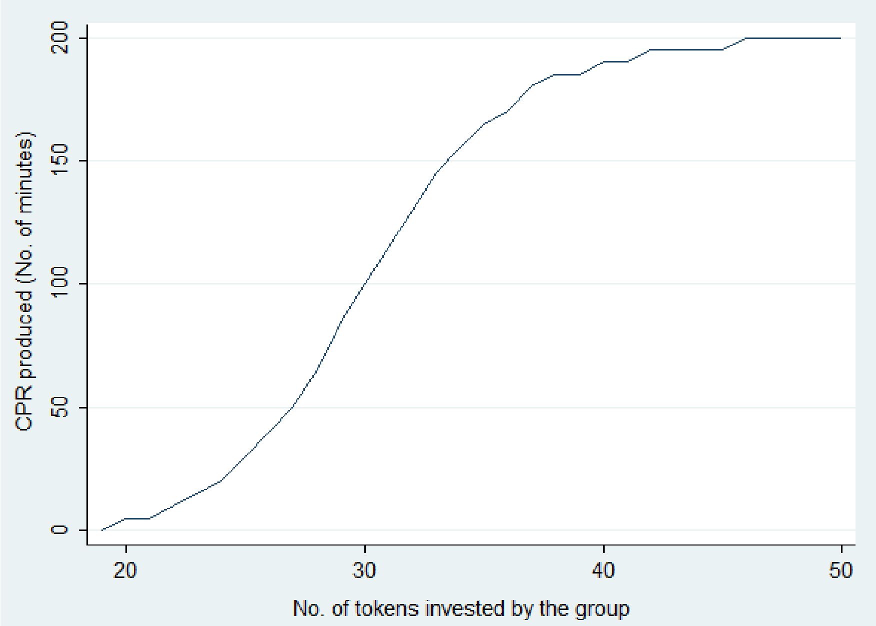
We designed artefactual field experiments based on Cardenas' et.al (2008) and largely follow the experiment design of Janssen et al. (2011). Cardenas' et.al (2008) "Irrigation Game" incorporates the most important elements of irrigation system; namely the need to coordinate asymmetric appropriation. These experiments were performed in two phases without (baseline) and with institutional interventions (treatment phase). Each experiment group first conducted the baseline version before the treatment was introduced in the second phase of the experiment. The baseline phase of the experiment took fix seven rounds. The duration of the treatment phase varied randomly between 8 and 11 rounds.

In each experiment session four groups were established consisting of 5 members. After the end of the baseline phase each group was randomly assigned to one of four treatments.

All participants were provided with the same initial endowment and within each group every player was randomly assigned to a unique location. This position determined the sequencing of extraction decisions and remained fixed throughout the experiment.

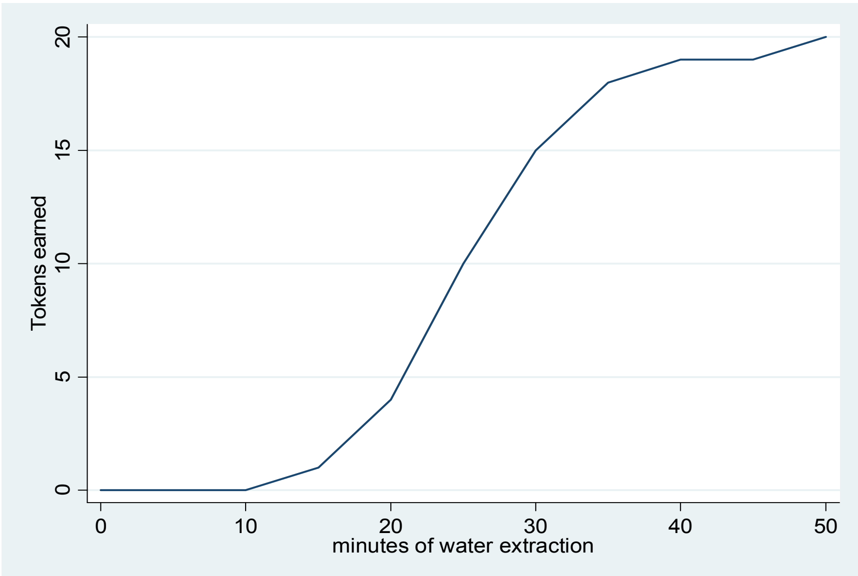
During the baseline phase of the experiment two decisions where repeated in every round. Firstly, all participants decide simultaneously on the number of tokens they want to invest in maintaining the irrigation infrastructure. Non-contributed tokens are kept in a private account. The collective investment is the simple additive function of all group members' individual investment, where each member's contribution carries the same weight. After all group members decided on their contribution the total amount of common good produced was communicated to all players. The relationship between collective investment and CPR produced is determined by a sigmoidal production function similar to the one used in Janssen et al. (2011) (Figure 2). This function captures the essential aspects of irrigation systems. For low levels of overall contribution very little CPR is produced. Like in real-life, no single player on its own is able to provide enough investment to produce a meaningful amount of CPR. After a certain threshold any additional contribution raises the amount of CPR produced appreciably. This represents the potential benefits of proper infrastructure in providing additional amount of water. At higher levels of overall investment we observe declining marginal productivity of additional units.

Figure 2: *CPR production function (Based on Janssen et al. (2011)*



Secondly, the players make extraction decisions in the sequence of their assigned location. The extraction decision of the first mover imposes a negative externality on all other players as the amount of CPR available for subsequent players depends upon this decision. All decisions made by an individual are transparent to all other players. Total earnings for an individual in a round are determined by the amount of water used by this particular individual plus the amount of initial endowment not invested and kept in the private account. The relationship between the amount of water used and tokens earned is also denoted by an S-shaped function where initially the marginal return is very low, more and more increasing until it decreases again for very high values (Figure 3).

Figure 3: Pay-offs depending on the water extraction decisions (Based on Janssen et al. (2011)



During the treatment rounds, players have to make three decisions: 1) the provision decision as in the baseline phase; 2) the appropriation decision as in the baseline phase; and 3) the decision whether to execute an institutional treatment against particular players. All treatments are costly and do not provide any direct monetary benefit to the executing player. We apply three types of treatment. The first treatment is face-to-face communication where players can directly talk to each other. The second treatment is external sanctioning where players can decide to invoke third-party punishment against other participants. If external sanctioning is applied against a player there is still a one third probability that the punishment is not being effective. This reflects the real life situation of transaction costs in the executive system and the chance to get away with offences. If the punishment is effective the payable amount is fixed to four tokens. The third treatment is simulating conflict resolution by traditional authorities. During the treatment phase, elder(s) representing traditional authorities observe all the actions of the respective treatment group. If one player invokes this treatment it means that the elder will conduct discussions with the relevant parties in the presence of all other players. All the action and demands of traditional leader remain non-binding for each player. In the case of the fourth treatment players can choose between any one of these three mechanisms: Communication, Traditional leadership, or Third-party sanctioning.

4 Theoretical predictions

If a player invests nothing he remains with his initial endowment of 10 tokens. His earnings are zero if a player invests all her initial endowment and gets nothing from the water consumed. This could be the case either if he willingly or unwillingly consumes no water or he willingly or unwillingly consumes water at levels which do not result in any earnings. A player can earn 20 tokens if he invests all his endowment and extracts water for the maximum possible time of 50 minutes. If a player invests nothing in the provision of the resource but extracts water for the maximum possible time he earns 30 tokens - 10 tokens from his initial endowment and 20 tokens from consumption of 50 units of water. This is the maximum amount of earnings possible in a single round.

Head-users are especially tempted to play the lastly described strategy. Nevertheless, each player has the incentive to play this strategy if given the opportunity to do so. As a consequence, the prediction would be that no player invests in providing the common-pool resource and hence nothing is produced. No player earns anything from resource appropriation and the total earnings for each individual are equal to their initial endowment of 10 tokens. This is the sub-game perfect Nash equilibrium.

In order to describe the cooperative equilibrium we look at the group earnings rather than at individual earnings. The cooperative equilibrium could be better understood as a situation which maximizes social efficiency i.e. for the group (society) as a whole. The maximum level of group earnings that could be achieved in our experiment design is 104 tokens. There are many strategies that could result in this situation. They all have in common that the group members have to invest all together 37 or 38 tokens into the CPR. This results in 180 or 185 possible minutes of water extraction. Note that this situation can be achieved by each player contributing nearly equally or alternatively by some players bearing most of the responsibility while others pay smaller amounts.

Providing optimal amounts of the CPR does not guarantee that socially optimal appropriation is achieved. The later requires that appropriation of water is also done in an efficient manner. Because tokens earned from utilizing water depend upon a sigmoidal function any individual's under or over utilization of water results in welfare losses for the group. Assuming the social optimal investment of 37 tokens allows at maximum to extract water for 180 minutes resulting in 91 tokens earned. This situation can be achieved if four players extract 35 units of water (earning 18 tokens each) while only one player can extract 40 units (19 tokens). There are only 5 different permutations of strategies through which such an outcome could be achieved. Given that 13 (50-37) tokens were saved in the investment stage, this results in a maximum possible group earning of 104 (91+13) tokens.

The above described strategies are only a tiny part of the strategy space available to each player. Therefore attaining socially optimum level of earning requires considerable coordination and cooperation.

5 Results

The average investments in the baseline phase were 7.30 tokens which is approximately 70 per cent of the individual endowments. The average investment level remained stable throughout this period[7]. Only 1.7 per cent of observations conform to the Nash strategy of zero contribution, whereas the maximum possible investment is the most frequently chosen strategy with about 25 per cent of the observations. The average group investment was about 36.28 tokens and remained stable throughout the baseline rounds[8]. With this result the average investment is very close to one of the social optimal CPR provision points which would be 37 tokens. In none of the rounds group investment falls to zero.

The average individual extraction level during the baseline phase was 30.21 minutes. It was again stable over the rounds[9]. In nearly 14 per cent of the cases a player extracted the maximum amount of water.

Individual level average earnings for the baseline rounds are 15.40 (7.40) tokens. In only 1.79 per cent of the cases a player earns nothing whereas in approximately 70 per cent of the observations player earnings are greater than 10 tokens (Nash equilibrium). Average group earnings for the baseline rounds are 77.01 tokens which is 74 per cent of the social optimum and 154 per cent of the Nash equilibrium. Figure 4 illustrates the group earnings as a function of group investments.

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[7] P-value for two-tailed t-test between first and seventh rounds is 0.583, which shows that we cannot reject the null hypothesis that the mean for both the sample is statistically the same.

[8] P-value for two-tailed t-test between first and seventh rounds is 0.690, which shows that we cannot reject the null hypothesis that the mean for both the sample is statistically the same.

[9] P-value for two-tailed t-test between first and seventh rounds is 0.720, which shows that we cannot reject the null hypothesis that the mean for both the sample is statistically the same.

In a next step we take a closer look at the role of the assigned position in the game. All group members independent of their position have very similar overall average investment level[10] (Figure 5). Players in all positions invest on average approximately seven tokens.

*Figure 4: Group earnings as a function of group investment. X-axis shows the level of group investment. Y-axis shows group earnings (Total number of observations = Total number of groups*number of baseline rounds = 32*7 = 224) Red lines show the social optimal provision and appropriation.*

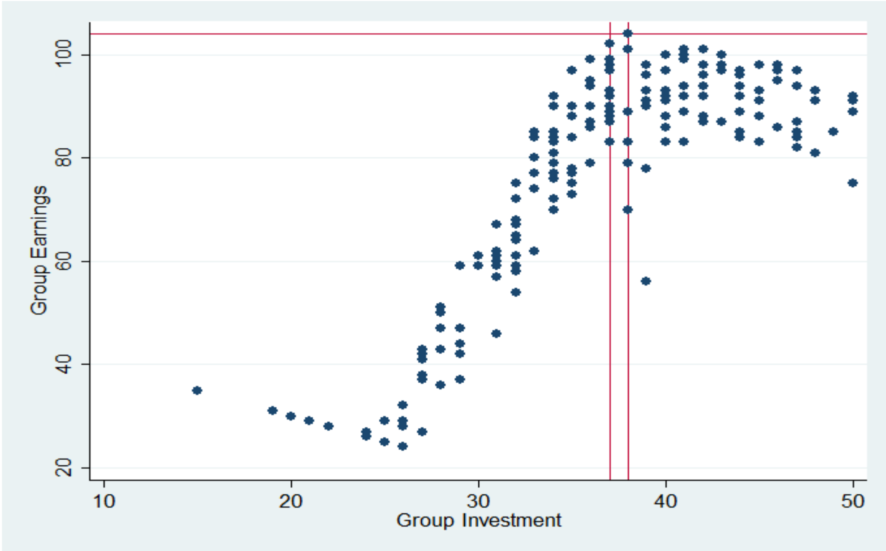
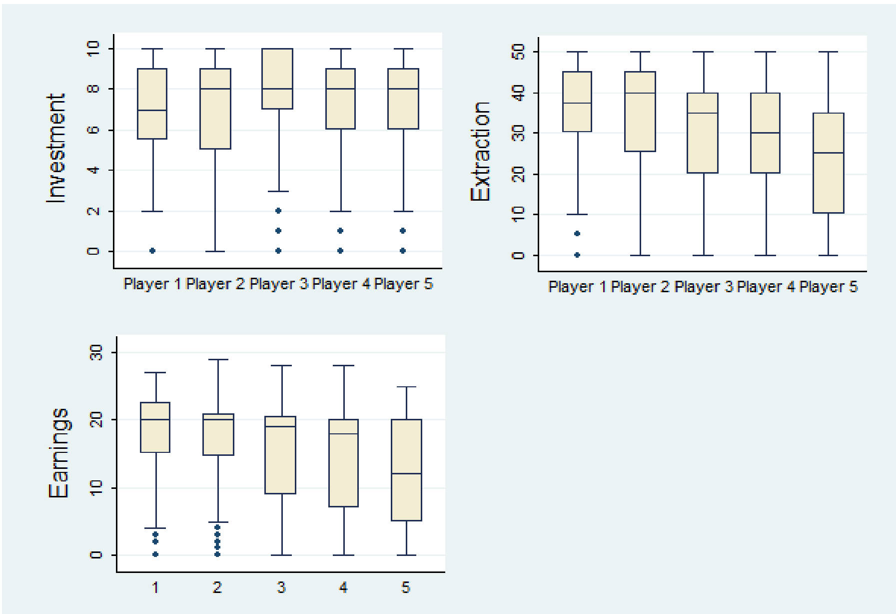


Figure 5: The distribution of investments, appropriations and earnings during the baseline phase by player position



Contrary to investment levels the average extraction level declines considerably for those with less preferential CPR access. Wilcoxon Matched-Pairs Signed-Ranks Tests shows that only the comparison between players one and two as well as between player three and four show no significant differences. For all other pairs the more preferential player appropriated significantly more (Appendix 1). Tail-users account for approximately 60 per cent of zero extraction cases while head users account for 60 per cent of the maximum extraction cases. The results for the individual earnings are consistent with the ones for the extraction.

We further observe that the CPR appropriation is the more unequal the lower the provision of the CPR (Figure 6). This provides incentives especially for tail-users to over-provide the CPR (greater

[10] Wilcoxon Matched-Pairs Signed-Ranks Tests show no significant difference between positions. See Appendix 1 for more detailed results.

than the socially optimum level).

We now turn our attention towards the effect of the introduction of institutional incentives. As explained above, after the seventh round we introduced four treatments to different groups. These treatments are henceforth referred to as a) Communication, b) Traditional authority, c) external sanctioning, and d) Institutional Choice.

Figure 6: Average share of extraction for different group members as a function of CPR produced

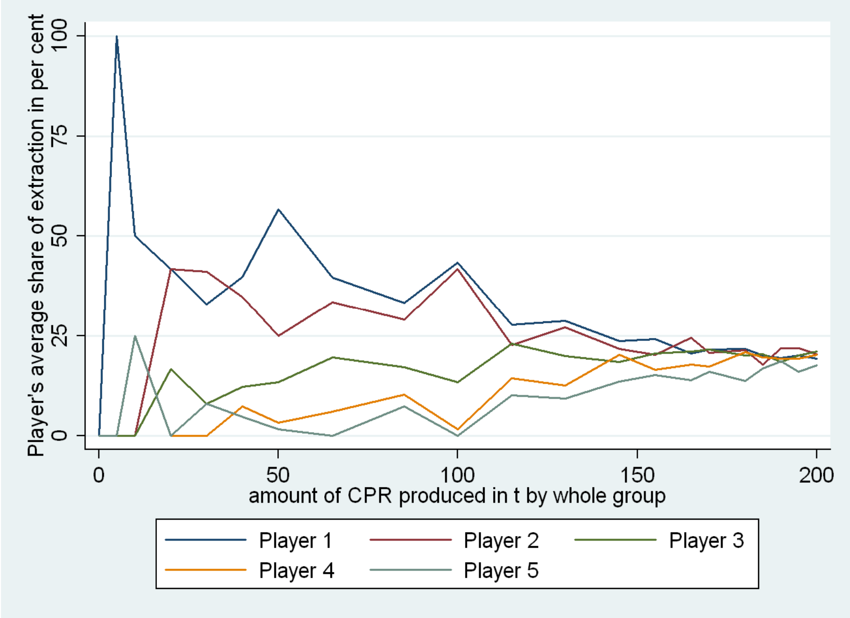
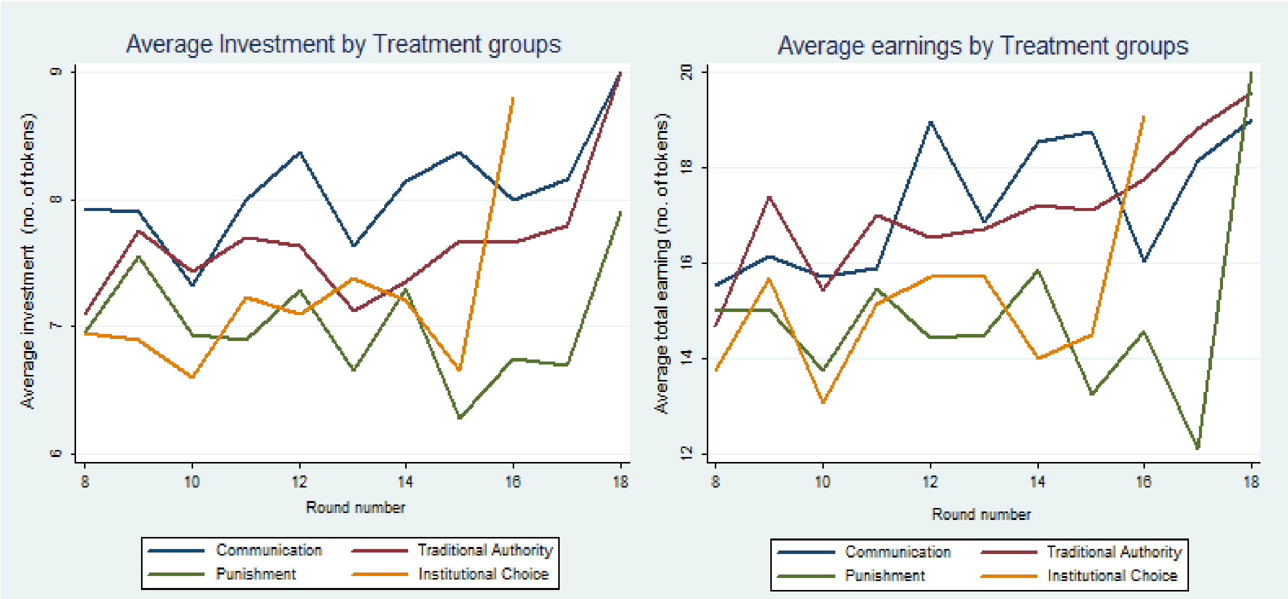


Figure 7 illustrates the average investment and earning level during the treatment rounds. Even though the figures suggest higher provision and appropriation levels for the Communication and Traditional authority groups, Mann–Whitney significance tests provides for only very few pairs any evidence for significant differences between the treatments (Appendix 2).

Figure 7: Development of average provision and appropriation by institutional settings



Taking into account the complexity of the experiment we decided to use multivariate methods to analyze the players' decisions. We use a Random-effects regression model with independent variables only directly related to the experiment.

Table 2 confirms that there are no significant differences in the investment levels between different treatments. Nevertheless, the analysis provides evidence that the earnings of the Communication and Traditional Authority groups are significantly higher than of the external sanctioning groups. The groups having a choice between institutions did not earn significantly more than the sanctioning groups.

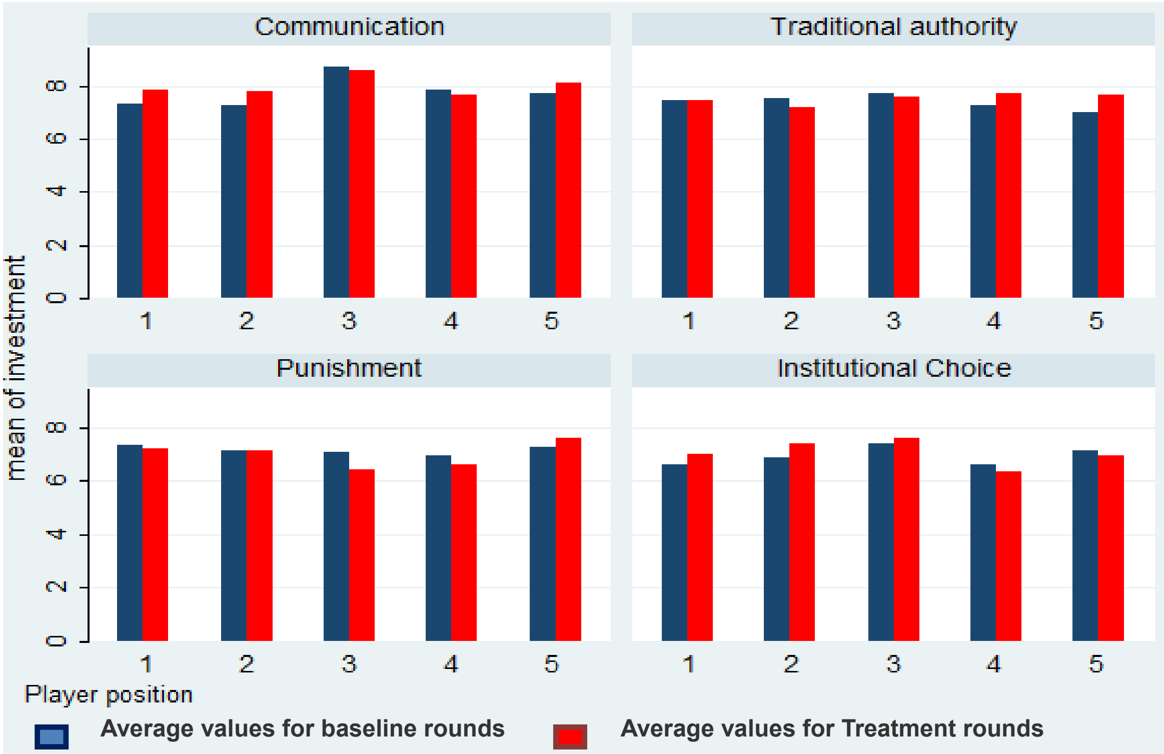
*Table 2: Random-effects regression results of investment and earning levels during treatment rounds for different treatment groups (coefficients and cluster robust standard errors[11] in parenthesis, *** $p < 0.01$, ** $p < 0.05$)*

Independent Variables	**Investment**	**Earnings**
Round number	0.018 (0.022)	**0.176 (0.004)*** **
Communication	0.410 (0.338)	**1.811 (0.867)** **
Traditional authority	0.275 (0.288)	**1.883 (0.826)** **
Institutional Choice	0.178 (0.289)	0.504 (0.928)
Punishment	Reference	Reference
Group Investment (t-1)	**0.059 (0.014)*** **	-
Extraction (t-1)	-0.008 (0.006)	-
Average investment during baseline rounds	**0.568 (0.093)*** **	
Average earnings during baseline rounds	-	**0.409 (0.073)*** **
Share in group investment (t-1)	-	-0.296 (3.634)
Share in earnings (t-1)	-	**6.883 (3.556)*** **
Constant term	0.862 (0.738)	**5.034 (1.406)*** **
Number of players	160	160
Number of observations	1450	1450

The two models indicate that the earnings in tendency increase over the treatment rounds despite the investment levels being rather stable. This can be interpreted as a sign that the players managed to allocate the water in a more efficient way. Therefore, we shift our attention towards the affect of the player position on their investment and extraction decisions. Figure 8 compares the investment level by treatment and player position between the baseline and treatment phases of the experiment. The graphical analysis shows only slight changes and more sophisticated methods are needed. We therefore calculated separate Fixed-effects models for players in different positions as well as for the different treatments. We divide the players into three subgroups; head-users (position 1 or 2), middle-users (position 3) and tail-users (position 4 or 5). This allows us to perform deeper analysis by looking at the effects of treatments on each specific sub-group. The regression models (Appendix 3) confirm the first impression of the graphical analysis: For none of the treatments and none of the player positions there is a significant change in the amount invested in the CPR from the baseline to the treatment phase of the experiment.

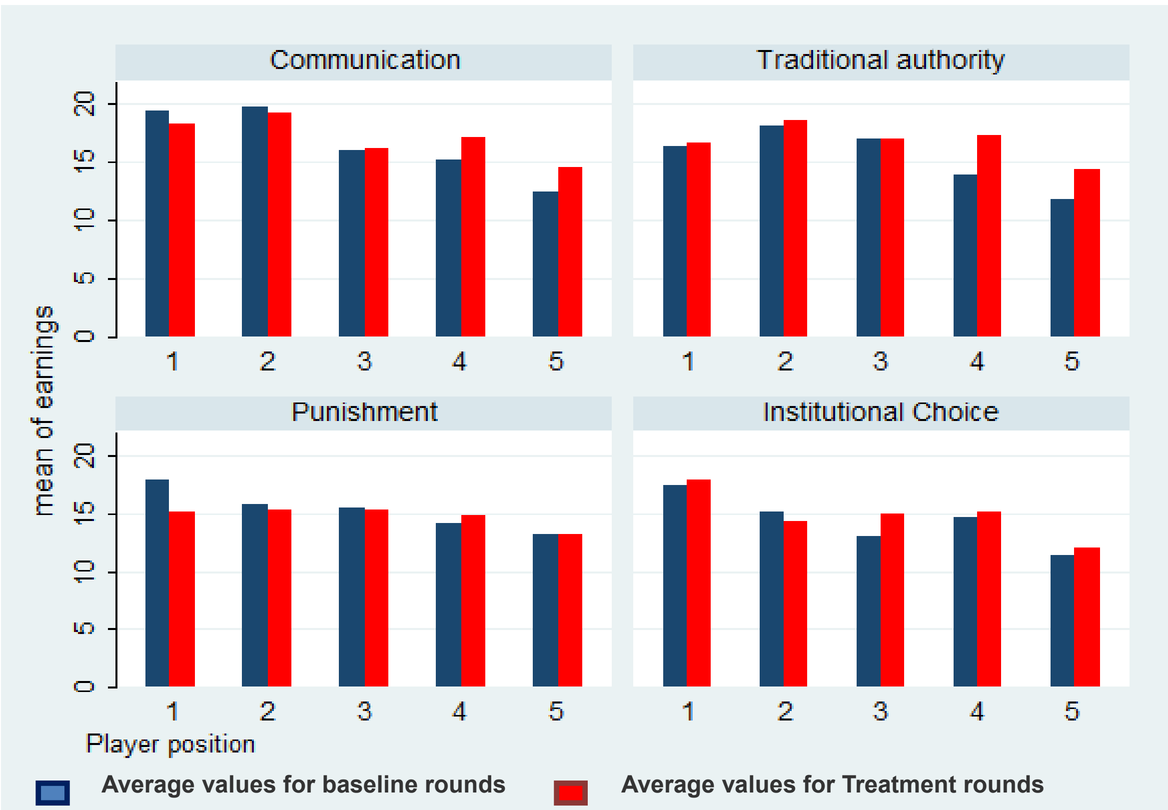
[11] We computed a Modified Wald statistic for group-wise heteroskedasticity in fixed effect models which confirmed (expected) heteroskedasticity in our data set. We therefore calculated cluster robust standard errors.

Figure 8: Average investment by position before and after the introduction of treatments.



In a next step we had a closer look at the earnings of different players. Figure 9 illustrates the average extraction of players by positions and treatments. We observe a strong increase in the earnings of tail-users of the Communication and Traditional authority treatments.

Figure 9: Average earnings by player position for different treatments.



We calculated again separate Fixed-effects models for players in different positions as well as for the different treatments in order to test for the statistical significance of developments. We present the results of the regression models in Table 3.

*Table 3: Fixed-effects regression models explaining the earnings by player positions and treatments (Coefficients and cluster robust standard errors in parenthesis, *** p< 0.01, ** p< 0.05, * p< 0.1)*

Independent Variables	**Communication**	**Traditional authority**	**Punishment**	**Institutional Choice**
Head-users (players 1 and 2)				
Experiment phase	-0.784 (0.541)	-0.348 (0.524)	-1.623 (1.306)	0.164 (1.123)
Gini extraction (t-1)	**-3.767(1.998)***	-1.276 (3.842)	-4.895 (6.003)	2.166 (3.840)
Share in investment (t-1)	**8.073 (4.187)***	11.185 (9.478)	-5.009 (7.213)	-7.076 (5.672)
Earnings (t-1)	0.076 (0.076)	**-0.177 (0.085)***	-0.057 (0.110)	**-0.110 (0.053)***
CPR produced	**0.062 (0.009)*****	**0.056 (0.011)*****	**0.050 (0.015)*****	**0.069 (0.011)*****
Constant	5.407 (2.102)***	9.746 (3.056)***	12.613 (4.761)**	9.143 (2.625)***
No. of players	16	16	16	16
No. of observations	248	248	240	228
Prob>F	0.000	0.000	0.000	0.000
R^2	0.276	0.090	0.283	0.327
Middle-users (player 3)				
Experiment phase	0.492 (0.818)	-0.898 (1.283)	0.868 (1.490)	**2.055 (0.778)****
Gini extraction (t-1)	7.800 (5.849)	**8.945 (3.932)***	3.089 (6.262)	6.870 (7.983)
Share in investment (t-1)	**17.710 (7.948)***	-9.860 (12.600)	2.231 (10.058)	-6.928 (4.918)
Earnings (t-1)	0.266 (0.141)	0.019 (0.101)	0.122 (0.157)	0.098 (0.112)
CPR produced	**0.103 (0.008)*****	**0.081 (0.011)*****	**0.068 (0.013)*****	**0.088 (0.006)*****
Constant	-10.940 (4.814)*	4.743 (3.261)	2.126 (4.429)*	-0.887 (4.147)
No. of players	8	8	8	8
No. of observations	124	124	120	114
Prob > F	0.000	0.000	0.000	0.000
R^2	0.593	0.414	0.458	0.509
Tail-users (players 4 and 5)				
Experiment phase	**1.484 (0.781)***	**1.757 (0.811)****	0.879 (0.894)	0.361 (0.853)
Gini extraction (t-1)	**9.147 (4.716)***	1.525 (3.587)	**6.909 (3.452)***	-2.285 (5.409)
Share in investment (t-1)	**-9.968 (4.355)****	-4.020 (8.289)	1.155 (5.282)	7.453 (6.763)
Earnings (t-1)	0.263 (0.085)***	0.054 (0.076)	0.117 (0.085)	-0.035 (0.095)
CPR produced	**0.069 (0.011)*****	**0.095 (0.010)*****	**0.070 (0.009)*****	**0.082 (0.008)*****
Constant	-0.654 (3.018)	-1.850 (2.194)	0.311 (2.431)	0.953 (2.653)
Number of players	16	16	16	16
Number of observations	248	248	240	228
Prob > F	0.000	0.000	0.000	0.000
R^2	0.483	0.415	0.451	0.332

The models provide evidence that the earnings of head-users in the Communication, Traditional Authority and Institutional Choice groups do not significantly change between the baseline and treatment phase of the experiment. In contrast, head users in the External Sanctioning groups earn significantly lower amounts during the treatment phase. Earnings of the middle users do not change for any of the treatments. As suggested by the graphical analysis, the tail users of the Communication and Traditional authority treatments receive significantly higher returns during the treatment phase. No differences are observed for tail-users of the External Sanctioning and Institutional Choice groups. We want to emphasise again that the earnings are determined by a sigmoidal function (Figure 3). Therefore it is not inevitable that increased earnings for tail-users necessarily imply decreased earnings for others. Rather it may very well indicate that participants distribute resources in a much more efficient way where each marginal unit of resource creates greater value.

As a last step of our analyses we look at the overall welfare effects on the group level. Also on the group level we can not observe any significant difference in the amount invested between the baseline and treatment phase of the experiment (Appendix 4). Further, our Fixed-effects models explaining the development of the groups' total earnings reaffirm that the only significant effect of the institution on group earnings occurs for traditional authority groups (Table 4). The group welfare increases when participants are given the opportunity to invoke traditional authorities for conflict-resolution purposes.

*Table 4: Regression results for group earnings (Coefficients and robust standard errors in parenthesis, *** p< 0.01, ** p< 0.05, * p< 0.1).*

	Communication	**Traditional authority**	**Punishment**	**Institutional Choice**
Experiment phase	0.151 (2.343)	**8.260 (3.459)***	-1.321 (2.170)	5.566 (4.353)
Gini Investment	**-130.325 (29.826)*****	**-112.801 (22.915)*****	**-102.715 (24.442)*****	**-160.134 (22.059)*****
Gini extraction (t-1)	-3.228 (15.673)	5.947 (7.412)	-19.046 (11.215)	2.772 (6.310)
Gini Investment (t-1)	14.070 (17.139)	-36.261 (22.614)	-8.162 (17.569)	20.727 (15.812)
Constant	**99.146 (2.070)*****	**93.610 (5.116)*****	**98.551 (3.054)*****	**89.694 (3.278)*****
Number of observations	124	124	120	114
Number of groups	8	8	8	8
Prob > F	0.000	0.000	0.000	0.000
R2	0.4113	0.278	0.430	0.502

6 Discussion

Even without any option to communicate or institutional incentives the players in our experiment provide the common pool resource to a level of approximately 70 per cent of the maximum possible investment. This average level of investment is maintained throughout the baseline rounds .This result is congruent with previous evidence in public good experiments where participants in the starting round of one-shot and repeated games exhibit virtually the same level of contribution. Nevertheless, one of the most consistent findings in experimental literature is that in the absence of the ability to communicate or sanction, the level of investment falls to only 30-40 per cent of players' endowment (see for example Fehr and Gächter, 2000, and Ostrom et al., 1992). In contrast, during our experiments participants maintain their level of investments even in the latter rounds of the baseline phase.

There could be several explanations for this behavior. In most other studies participants do not know each other very well; their interaction in real-life is limited. In contrast, most of the participants in our experiments deal with each other on almost daily basis. A lot of this interaction is guided by a set of social rules and norms established over a long period of time. Carpenter and Seki (2010) show that participants, who have prior experience in dealing with social dilemma situations underlying the game settings, exhibit markedly different behavior than students who are not experienced in the underlying social dilemma situations. Henrich et al (2010) suggests that participants interpret the experimental settings by relating them to their real-life experiences. In our case the provision of labor and resources for the management of irrigation infrastructure is a well known and typical challenge of the experiment participants. It is likely that the studied community has developed strong norms which help them to overcome the social dilemma. Ghate et al. (2011) observe that small communities with a shared history of social norms tend to be more cooperative even in the absence of face-to-face communication.

Another option could be that the players used non-verbal communication (e.g. facial expressions) to coordinate. We did not observe such behavior during the experiment but it should be considered as possible explanation.

The above mentioned result is more striking as the earnings from the experiment are not equally distributed amongst the players. Players in advantageous position with preferential access to the common-pool resource have significantly higher earnings as a result of higher levels of appropriation. This is consistent with the findings of other studies on asymmetric access (see e.g. Budescu et al., 1997; Cardenas et al., 8; Janssen et al., 2011). It could be expected that the ones who lose out punish the winners by withdrawing their contributions. This is not the case.

There are very persuasive arguments suggesting that in stable groups, head-users invest significantly more than their tail-end counter-parts. Nevertheless, our results suggest that this is not the case; participants invest on average similar amounts regardless of their position in the irrigation system. In the studies of Cardenas et al. (2008) and Janssen et al. (2011) average investment levels differed with tail-users contributing less than head-users. In contrast, Punjabi farmers in our study exhibit much more tolerance when facing inequalities in earnings.

As it seems, local farmers' norms regulating extraction decisions are weaker in comparison to norms guiding their decisions on the provision of pubic or common goods. It turned out that during discussions after the experiment different participants had different views on what constitutes a "fair share". This situation could be related to the present and the past frameworks governing the use of irrigation resources in this area. In both cases, the responsibility of the maintenance of watercourses remained under the domain of groups of farmers that utilize these facilities (de Klein, 1998). Often tail-users are the ones that encourage others to invest in the irrigation infrastructure. They most strongly rely on well-maintained and extensive irrigation systems. It should be noted that in our experiment tail-users earn more than they would get in a fully non-cooperative setting as predicted by the Nash equilibrium. Furthermore, tail-users' share of extraction increases with the amount of CPR produced. Both of these facts suggest that tail-users have some incentives to invest in the provision of CPR.

At the same time, only exceptionally head-users were fully free-riding. In most cases they showed some restrain in their extraction decision and did not extract the maximum possible water quantity. They were taking the needs of the later users into account. This suggests that head-users understand the importance of sharing the CPR produced with tail-users. The implicit threat of withdrawing or reducing cooperation might play some role in restraining head-users' extraction decision. The head-users consideration, however, could also be interpreted as a sign of social norms. Taking these two results in conjuncture we find evidence in support of Singleton's and Taylor's (1992) concept of cooperation based on mutual vulnerabilities.

The introduction of institutional interventions had no significant effect on the overall level of investments and hardly on the earnings. One explanation for the limited effect is the already very high provision level of the players during the baseline rounds. It is difficult to improve this outcome. Secondly it could be argued that the treatments actually affected the investment behavior by avoiding a decline in contributions as observed in many other experimental studies.

The treatments support the groups, however, to distribute their resources more efficiently. We suspect that the participants use the External Sanction treatment as a low-cost retaliatory option. The costs of withdrawing cooperation are perceived to be higher than the transaction costs associated with punishments. As a result, the sanctioning mechanism is effective in reducing the extraction levels of head-users. Nevertheless, this does not translate into a beneficial effect for tail-users' earnings or overall group welfare because the institution does not help the groups to focus on pro-social norms leading to higher investments.

In contrast, the overall welfare of the group rose with the introduction of the Traditional authority institution. We further observe that in particular tail-users benefit from the introduction of the Communication and Traditional Authority treatments. Both treatments give participants an opportunity to directly coordinate. Further they inhibit the possibility to use social enforcement mechanisms (see also Falk et al. 2012). The Communication treatment allows applying only horizontal social consequences while under the Traditional authority rule a vertical sanctioning mechanism is added. Through a process of discussion guided by influential elders it induces focus on pro-social norms without compromising on the opportunity to punish undesired behavior.

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Appendices

Appendix 1(a): p-values of two-tailed Wilcoxon Matched-Pairs Signed-Ranks Test statistics for the number of tokens invested for the provision of CPR by players at different positions during the baseline phase of the experiment (32 observations for each position).

	Player 2	Player 3	Player 4	Player 5
Player 1	0.9925	**0.0667**	0.4431	0.6875
Player 2	-	0.2169	0.8224	0.779
Player 3	-	-	0.1471	0.1298
Player 4	-	-	-	0.9701

Appendix 1(b): p-values of two-tailed Wilcoxon Matched-Pairs Signed-Ranks Test statistics for earnings by players at different positions during the baseline phase of the experiment (32 observations for each position).

	Player 2	Player 3	Player 4	Player 5
Player 1	0.9925	**0.0065**	**0.006**	**0.0006**
Player 2	-	0.0641	**0.0122**	**0.0016**
Player 3	-	-	0.2578	**0.0047**
Player 4	-	-	-	**0.0107**

Appendix 2: p-values of Mann–Whitney test results for differences in investments, extraction level and earnings between different treatments during 8 treatment rounds (C = Communication treatment, TA = Traditional Authority treatment, P = External Sanction treatment, IC = Institutional Choice treatment).

	Investment	Extraction	Earnings
C and TA	0.4622	0.5286	0.5995
C and P	0.1559	**0.0929**	0.1152
C and IC	0.2076	0.2936	0.1415
TA and P	0.4622	0.3446	0.2936
TA and IC	0.5995	0.4306	0.2936
P and IC	0.9164	0.9164	0.9581

*Appendix 3: Fixed-effects regression models explaining the individuals' investments depending on their assigned position and treatment (coefficients and cluster robust standard errors in parenthesis, *** p< 0.01, ** p< 0.05, * p< 0.1)*

Independent Variables	Communication	Traditional authority	Punishment	Institutional Choice
Head-users (players 1 and 2)				
Experiment phase	0.428 (0.348)	-0.254 (0.313)	-0.100 (0.418)	0.303 (0.306)
Gini earnings (t-1)	-2.129 (1.823)	-1.014 (1.299)	**-5.565 (1.237)*** **	-1.991 (1.207)
Share in investment (t-1)	-0.695 (3.307)	-5.842 (5.292)	-3.922 (2.556)	**-3.179 (1.422)** **
Earnings (t-1)	-0.023 (0.031)	0.044 (0.033)	-0.013 (0.026)	-0.005 (0.023)
Constant	8.235 (1.090)***	8.122 (1.367)***	9.271 (0.576)***	8.001 (0.415)
No. of players	16	16	16	16
No. of observations	248	248	240	228
p>F	0.464	0.243	0.002	0.137
R^2	0.132	0.001	0.050	0.005
Middle-users (player 3)				
Experiment phase	-0.178 (0.279)	-0.217 (0.629)	-0.799 (0.834)	0.141 (0.470)
Group earnings (t-1)	0.426 (1.408)	-2.207 (2.371)	-3.098 (2.060)	-3.200 (2.267)
Share in investment (t-1)	1.423 (2.168)	5.084 (3.140)	-6.617 (7.444)	0.807 (2.302)
Earnings (t-1)	0.011 (0.032)	0.038 (0.028)	-0.003 (0.060)	**-0.068 (0.030)***
Constant	8.182 (0.825) ***	6.507 (1.055) ***	9.067 (2.659)	8.866 (0.720)***
No. of players	8	8	8	8
No. of observations	124	124	120	114
p>F	0.823	0.333	0.339	0.009
R^2	0.037	0.066	0.009	0.046
Tail-users (players 4 and 5)				
Experiment phase	-0.116 (0.393)	0.530 (0.316)	-0.091 (0.350)	-0.205 (0.229)
Gini earnings (t-1)	-5.431 (2.362)	-2.274 (2.183)	**-6.992 (3.306)***	**-3.243 (1.129)** **
Share in investment (t-1)	4.842 (3.390)	-2.108 (4.688)	-0.623 (2.178)	-0.149 (3.705)
Earnings (t-1)	-0.054 (0.031)	-0.024 (0.018)	-0.004 (0.036)	**-0.064 (0.022)*** **
Constant	8.640 (1.068) ***	8.342 (0.629) ***	8.662 (1.315) ***	8.360 (0.891) ***
No. of players	16	16	16	16
No. of observations	248	248	240	228
p>F	0.140	0.127	0.154	0.049
R^2	0.085	0.011	0.065	0.013

*Appendix 4: Regression results for group investments (Coefficients and robust standard errors in parenthesis, *** p< 0.01, ** p< 0.05, * p< 0.1).*

	Communication	**Traditional authority**	**Punishment**	**Institutional Choice**
Experiment phase	0.519 (1.869)	0.772 (1.780)	-1.041 (2.172)	1.005 (1.435)
Gini extraction (t-1)	-2.968 (8.497)	5.031 (8.867)	**-16.012 (3.101)***	**-6.607 (3.074)**
Group earnings (t-1)	-0.002 (0.085)	0.044 (0.056)	0.006 (0.062)	**-0.076 (0.017)**
Constant	**41.712 (9.096)***	**35.023 (5.928)***	**39.887 (5.590)***	**44.281 (1.746)***
Number of observations	124	124	120	114
Number of groups	8	8	8	8
Prob > F	0.857	0.183	0.002	0.088
R^2	0.089	0.111	0.188	0.043