Addressing the institutional challenges of groundwater management in areas of rapid urbanization

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Rapid urbanization in semi-arid and arid areas challenges the provision of water for the urban population. Moreover, the rise in population does not only increase directly but also indirectly the water stress through a higher demand of water-intense agricultural products. This demand is often met by exploiting groundwater stocks. The consequences are overdrafted or exhausted aquifers. In order to prolong the life of the resource and to increase the long-term benefits for the users, management institutions are needed. However, these management institutions might not be stable as background conditions change during the process of urbanization. In this paper, we compare cooperative, non-cooperative and exogenous management institutions at different stages of urbanization. To do so, we have conducted a framed field experiment along the rural-urban gradient of the fast growing city of Bengaluru, India. Results indicate that both enabling and restrictive exogenous institutions are the most efficient in prolonging the life of the resource independent of the stage of urbanization. Nevertheless, the results also show that participants of more urbanized areas are more myopic than in rural sites stressing the importance of governance in these areas.

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Abstract

Rapid urbanization in semi-arid and arid areas challenges the provision of water for the urban population. Moreover, the rise in population does not only directly increase the water demand but also indirectly through a higher demand of water-intense agricultural products. This demand is often met by exploiting groundwater stocks. The consequences are overdrafted or exhausted aquifers. In order to prolong the life of the resource and to increase the long-term benefits for the users, management institutions are needed. However, these management institutions might not be stable as background conditions change during the process of urbanization. In this paper, we compare cooperative, non-cooperative and exogenous management institutions at different stages of urbanization. To do so, we have conducted a framed field experiment along the rural-urban gradient of the fast growing city of Bengaluru, India. Results indicate that both enabling and restrictive exogenous institutions are the most efficient in prolonging the life of the resource independent of the stage of urbanization. Nevertheless, the results also show that participants of more urbanized areas are more myopic than in rural sites stressing the importance of governance in these areas.

INTRODUCTION

In many arid and semi-arid areas with rapid urbanization the pressure on groundwater aquifers is critical. In South Asia, the region with the fastest growing cities in the world, more than half of the population depends directly or indirectly on groundwater (United Nations 2016). The growth in population has also increased the pressure on farmland, forcing farmers to intensify their agricultural production using groundwater (Shah 2014). In addition, water demand is driven by the improved purchasing power of the urban population. In particular the demand for water-intense cash crops has pushed the groundwater use for irrigation (Siebert *et al.* 2010). Associated problems of overdrafted aquifers are saltwater intrusion, land-surface subsidence or aquifer mining and pollution. Another consequence of extensive groundwater extraction is the reduction of surface water which is related to a decrease in ecosystems and their services (Shah 2014; WBGU 2016).

In order to avoid a fast depletion of groundwater in emerging cities and its surroundings, governance is needed. Groundwater is subtractable but users cannot be excluded. Therefore it belongs to the common-pool resources (CPRs). The design of CPR governance regimes depends on the socio-economic context of the users and the type of the CPR. Due to the invisible boundaries and the uncertainty of the stocks and flows, groundwater governance is challenging (Ostrom 1990). User whose economic activity highly dependents on groundwater usage are in a social dilemma: either maximize their short-term profits or ensure the sustainability of the resource.

To overcome this problem, many authors favor a combined governance system of governmental agencies and self-governed water-user boards. Rules and restrictions which are designed to maximize the long-term gains from the resource are implemented and monitored by an exogenous institution. These management institutions are considered to be very efficient to overcome the social dilemma and prolong the life of a CPR (Brozović, Sunding & Zilberman 2006; Ross & Martinez-Santos 2010). However, this line of reasoning is not shared by all authors. Meinzen-Dick *et al.* (2016) argue that in places where governmental institutions are weak, cooperation and collective action are more efficient. However, these cooperative institutions involve high transaction costs. When these costs are prohibitively high, Madani & Dinar (2012b) show that learning and the incorporation of external effects into individual decision-making can also lead to sustainably managed aquifers circumventing transaction costs. These management institutions are called non-cooperative management institutions.

These theoretical considerations show the complexity to govern a CPR but show at the same time several potential solutions. Nevertheless, it remains unclear how to design an efficient management institution in a real world setting.

The need for further research comes along with the question how to design different management institutions in order to face the challenges of urbanization. The process of urbanization is understood as a transformational process changing fundamentally the social-ecological system (SES). This process which is induced by a growing population may lead to a so called red trap in which over-consumption is not responded to an ecological decline (Cumming *et al.* 2014). Here management institutions also help to avoid the red trap. The literature has shown that background processes are important for the success of an institutional arrangement. For instance, Prediger, Vollan & Frölich (2011) show that culture and the ecological precondition require a different institutional setup for managing a CPR sustainably. However, it remains unclear whether different management institutions are needed in different stages of urbanization. For instance, transaction costs might be lower in rural sites where strong social networks exist than in fully developed anonymous urban areas.

In order to analyze these two research gaps, a framed field experiment was conducted. Field experiments have been used earlier in the context of CPR issues (Anderies *et al.* 2013; Janssen, Lindahl & Murphy 2015) but there are few in the context of groundwater use (Salcedo 2014; Meinzen-Dick *et al.* 2016). Lab experiments have been used more frequently in this field. Modifying the geohydrological background model assumptions of earlier theoretical work towards more realistic ones has had an impact on the behavior of the participants. As a result, policies based upon rational choice analysis needed to be reassessed (Suter *et al.* 2012; Liu *et al.* 2014). However, lab experiments have their drawbacks, too. One is the proneness to behavioral differences of users and non-users of a resource (Buchholz, Holst & Musshoff 2016). For example, Salcedo (2014) shows that most of the users of groundwater behave more pro-social and less myopic than non-users, e.g. students. Conducting experiments with actual users can reveal systematic differences between users of the resource and non-users, making the inference more robust towards real-world applications (Buchholz *et al.* 2016). As there is little knowledge about different user types, further insights are needed whether the user type has an influence on the outcome of the game.

Considering the different research gaps, it is unclear which management institution to choose. Due to the massive challenges of groundwater management in general and in the context of urbanization in particular, it is critical how to design a management institution. Therefore, the aim of the paper is threefold: First, cooperative, non-cooperative and exogenous management institutions are evaluated on their effectiveness to prolong the use of CPR. Second, we investigate how different institutions perform in the context of urbanization. Third, we compare how different user types behave differently in the experiment.

The framed field experiment was conducted with 600 participants along the rural-urban interface in Bengaluru, India. The city of Bengaluru in South India was chosen because it is characterized by a rapid growth in population and growing middle-class consumption. The lion's share of the demand for agricultural products is satisfied by local farmers which depend on groundwater for irrigation. Moreover, most of the city's water demand is satisfied by

groundwater. At the moment the groundwater level has drastically reduced and faces a red trap thread (Srinivasan *et al.* 2017).
Another objective of this paper is to provide inside for policy makers on the household decision-making in the context of rapid urbanization. These insides can be used to design adequate and efficient policies.

While many papers acknowledge the problem of the provision of water in urban areas, few have considered the effects of urban water demand on the surroundings. McDonald *et al.* (2011) have analyzed the impact of urban water demand on surrounding ecosystems. To our knowledge, this is the first paper which analyzes the effect of urbanization on agricultural water demand.

The remainder of the article is as follows: First, the literature is reviewed and the predictions of the experiment are discussed. Second, the experimental design as well as the study region is introduced. Third, the results are discussed while the last chapter concludes.

LITERATURE REVIEW AND PREDICTIONS

Due to its complexity, groundwater governance has received a lot of attention in the literature (Gardner, Moore & Walker 1997; Koundouri 2004). Groundwater governance sets and implements the rules, i.e. the institutions, for prolonging the life of a resource (Ross & Martinez-Santos 2010). In general, CPR governance frameworks can be categorized into three: (1) cooperative, (2) non-cooperative and (3) exogenous institutions (Madani & Dinar 2012b). Each governance approach has the ability to overcome the social dilemma but each has advantages and disadvantages.
Cooperative government institutions develop extraction rules based on group rationality in order to increase long-term gains for the whole group. Under these institutions, group gains are usually bigger than under the other regimes. The problems with cooperative institutions are high implementation and transaction costs (Madani & Dinar 2012a). Regarding the groundwater case, self-regulation (cooperative institutions) is even more difficult due to undefined boundaries of the resource and invisible stocks and flows which makes monitoring costly and hard to implement (Ostrom 1990; Madani & Dinar 2012b; Meinzen-Dick *et al.* 2016).
Non-cooperative institutions are management plans based on individual decision-making which takes into account externalities or heuristic extraction schemes based on learning. In a cooperative game-theoretical framework Madani & Dinar (2012b) show that these management plans do not always end up in the “tragedy of the commons”. The problem is that many users do not consider long-term effects of their action. Personal traits like environmental awareness, education, social trust, altruistic social value orientation are beneficial for the long-term consideration.
Exogenous institutions are imposed from outside. Two different kinds of exogenous institutions exist: restrictive and supportive institutions. External institutions can impose the social optimum but the outcome is unclear. Institutions can crowd-out the intrinsic motivation of prolonging the life of a CPR if the intervention is felt to be restrictive or crowd-in if the intervention is felt to be supportive (Frey & Stutzer 2006). However, a sanction might be felt to be supportive as trust and the degree of self-determination within the group are low (Vollan 2008). Nevertheless, the general view in the literature is that sanctions usually crowds-out intrinsic motivation while incentives crowd-in (Cardenas & Carpenter 2008; Narloch, Pascual & Drucker 2012).

The literature shows the complexity of the question which management institution to choose. In the following two subsections, two scenarios are discussed. First, we discuss different behavior types and second, management institutions in the light of urbanization.

Behavior type and management institutions

One of the determinants of success of the management institution is the behavior type of the users. Three types can be distinguished: Myopic, rational and optimal (Suter *et al.* 2012). The myopic type maximizes profits but does not take into account decision of the others or long-term appropriation. The rational type maximizes profits but takes into account the long term implication of his current behavior while the optimal user type maximizes the profits under consideration of the action of the others and the long-term implications of today's action.
Regardless of the behavior type, Madani & Dinar (2012a) show that cooperative institutions are the most efficient in prolonging the life of a CPR and increasing the long-term gains of all group members. However, they also acknowledge that many factors such as the lack of trust and knowledge can undermine cooperative behavior. Furthermore, they show that cooperative benefits decrease the closer the user is to the optimal type. In a situation where users are non-myopic and sensitive to externalities, non-cooperative management institutions are more efficient due to a reduced transaction costs (Madani & Dinar 2012a, 2012b). When users are of the myopic type, then exogenous institutions are more efficient than the other two.
Considering the aforementioned pros and cons of different management institutions, we expect that cooperative management institution prolong the use of the resource and increase group benefits.

Which effect the exogenous management institutions have remains unclear due to the crowding-in–crowding-out problematic. On the one hand we expect strong social norms at least within the rural communities (Meinzen-Dick *et al.* 2016) which would diminish the effect of the restrictive exogenous management institutions. With supportive management institutions, we expect a positive effect. On the other hand, privately managed borewells only benefits individual households rather than the community. Therefore, regulation ensures that free-riding effects are diminished and cooperation is enhanced (Narloch *et al.* 2012).
Furthermore, we expect that regardless the management institution the non-myopic behavior type will not change his/her behavior.

Aside from the behavior type, several papers show that risk attitudes alter the effect of policy interventions. Under uncertain payoff structure, risk-neutral myopic users would not change their behavior in any of the treatments while rational individuals would adapt to the policy interventions (Cárdenas *et al.* 2017). On the other hand, irrigation is not only an important input factor in agriculture but also a drought control measure. Controlling for risk preferences can explain high water withdrawals due to downside-risks avoidance (Groom *et al.* 2008). Buchholz *et al.* (2016) stress the importance of risk attitudes: The more risk-averse the farmer, the more often irrigation occur. They also show that irrigation strategies remain stable across treatments and policy interventions. Therefore, we would expect an ambiguous effect on the overall extraction decisions.

Urbanization and management institutions

As little research has been done so far how urbanization influences household behavior and institutional processes, the effects are unclear so far. Nevertheless, the background setting is very important for the institutional arrangements of the CPR. Prediger *et al.* (2011) show that cultural and ecological preconditions determine the willingness to cooperate and hence to

prolong the life of a CPR. The overall effect of urbanization remains ambiguous though. On the one hand, trust levels may be diminished due to newly and densely populated areas. In addition, people who move to the city are usually looking for a brighter future and economic opportunities. On the other hand, their main source of income does not depend on agricultural production, so their main motivation could be to assure the existence of the resource.
Considering the effects of urbanization on the design of the management institutions, exogenous management institutions are more likely to account for the loss of trust and diminished social norms (Putnam 2000). Therefore, we would expect to see a strong effect of the restrictive exogenous management institutions and no effect of the cooperative and non-cooperative management institutions with increasing urbanization.

EXPERIMENTAL DESIGN

Aside from the CPR group game, a trust game and the Holt-and-Laury lottery (HLL) for risk preferences elicitation were carried out. The last three mentioned experiments were conducted within a socio-economic survey, which was carried out two to three weeks prior to the CPR experiment. The section will describe all four experiments briefly as well as introduce the study region and the sampling process.

Study region

The experiment was conducted with 600 households in two transects which covers urban, peri-urban and rural sites in the north and south of Bengaluru, India. The city of Bengaluru was chosen because it is rapidly expanding and therefore, transformational changes can be studied. Moreover, Bengaluru faces overdrafted aquifer and a fast declining groundwater table (Srinivasan *et al.* 2017). While many inner parts of the city are connected to the Bengaluru water and sewage system which gets water from the 300 km distant Cauvery River and do not depend on groundwater, newly developed parts of the city are not connected to the system yet. Their main water source remains groundwater.

In contrast to the upstream regions, the downstream areas carry water all year long due to the sewages of city coming from the Cauvery. This reduces the pressure on groundwater aquifer as sewage irrigation is a common practice. Nevertheless, weather patterns have shifted and droughts have occurred more often in recent years which have led to conflicts over the water rights of the Cauvery Rivery from several states along the river. Altogether, the usage of groundwater has become more important for agricultural production, increasing the pressure on groundwater.

Sampling

The sample was drawn in three steps. First, the villages within the two transects were stratified into six groups such that each group represents the state of urbanization. For the stratification the survey stratification index (SSI) which consists of the distance to the city center and the built-up density was developed (see Hoffmann *et al.* 2017 for more details on the SSI and the sampling procedure). After the stratification, 61 villages were randomly selected. Second, household lists from the angandwadis (kindergarten) were acquired. These household lists are updated regularly by the angandwadi-officers. 15 households were then randomly selected from the household lists. These 1,200 households were surveyed. Third, out of the 1,200 households 600 households again randomly selected for the participation in the experiment. In order to avoid spillover effects within a village, each group was randomly assigned to a treatment. While the survey was carried out between December 2016 and April 2017, the experiment was conducted between February and April 2017.

CPR game design

The framed field experiment conducted is a dynamic CPR game similar to the work of Janssen *et al.* (2012) and Meinzen-Dick *et al.* (2016). Due to the interlinkages of groundwater aquifers, the experiment was designed as a group experiment. In the experiment, each member of the group is an agricultural entrepreneur with water as the only input and the depth to groundwater as the cost influencing factor. For the underlying geohydrological dynamics of the groundwater which determines the groundwater level, the bathtub model was chosen. The bathtub model is a highly simplified model where extraction of one member has a direct effect on the groundwater level and thus affects the other immediately (Suter *et al.* 2012; Liu *et al.* 2014). For the ease of explanation and to keep it as simple as possible and within a reasonable time frame other geohydrological were not considered. Following Suter *et al.* (2012), Gardner *et al.* (1997), and Feinerman & Knapp (1983) the profit function for each participant follows a quadratic function:

$$\pi_{it} = \alpha x_{it} - \frac{\gamma}{2} x_{it}^2 - \phi d_t x_{it} \tag{1}$$

where π_{it} denotes the profit of player i in period t, α is the intercept and γ the slope of the demand curve, x_{it} is the quantity of the water applied. The last part of the equation indicates the cost part with ϕ as the cost parameter and d_t indicating the depth to groundwater in the particular period. The depth to groundwater itself is determined by the water pumped out by each individual of the foregone period. Using the underlying bathtub model the depth to groundwater function is given by

$$d_{t+1} = d_t + \frac{\sum_{i=1}^{n} x_{it} - r}{AS} \quad . \tag{2}$$

where r, denotes recharge rate and A denotes the area of the aquifer and S is the storativity. The parameters of the operationalized model are found in appendix 1. The parameters were taken such that it meets the local conditions. The values were taken from the Groundwater board of Bengaluru (CGWB 2015).

As farmers in the region do not measure the exact quantity of water applied on their fields, they could choose the pumping hours. One pumping hour represents 10 water units. This makes x_{it} a discrete variable. Moreover, pumping hours were limited as energy supply for the borewells is also restricted in the study region. The choice dimension reached from zero to 4 hours with half hour steps.

The experiment consisted of three sequences of the game: trial, baseline and treatment. Before the game we explained the rules and answered questions (description of the game on request). Each sequence consisted of five rounds. In each round, the choices of the farmers were written down on a decision sheet and handed back to the session leader who calculated the groundwater level of the sequent period. All decision had to be made privately and communication was not allowed during the game. Payoffs were announced only privately to each member of the group. After each sequence, the settings were set back to the initial level. The length of each sequence was not announced to avoid strategic behavior. The trial itself lasted for two rounds. Baseline and treatment lasted for five rounds. The length of each sequence was not announced to avoid strategic behavior.

After the baseline, four different management institutions were introduced. These treatments are defined as follows

Cooperative management institution (Communication): Only in this treatment communication with other group members were allowed. Before the start of each round, the participants had up to 5 minutes time to discuss the extraction strategy. After five minutes the decision were again made privately.

Non-cooperative management institution (Extraction heuristics/learning): In this scenario, the baseline scenario was repeated such that learning effects and extraction heuristics could have been deduced from the previous sequences.

Supportive exogenous management institution (Bonus): A reward of 100 token is paid for pumping up to one hour. This is the equal to the optimal user which is equal to one pumping hour for all group members such that the water level remains constant. The bonus is randomly rewarded to one group member. If the selected group member did not behave accordingly, the bonus was not paid.

Restrictive exogenous management institution (Bonus): A punishment of 100 token per half-an hour pumping time more than the optimal extraction rate. Like in the supportive exogenous management treatment the control is done randomly. If the selected group member behaved accordingly, the punishment was not applied.

Holt and Laury lottery

The Holt and Laury Lottery (HLL) is a measure to determine the risk attitude (Holt & Laury 2002). The method was already successfully carried out in different development countries (e.g. Moser & Mußhoff 2016).

We visualized the HLL with a decision card to make it easily understandable. The cards contained two blocks with lottery A and lottery B. Each block contains a high and a low payoff. In lottery A, the high payoff is 100 INR and the low 80 INR while in Lottery B, payoffs are 192 INR and 5 INR for the high and low payoffs, respectively. As the variation between the two payoffs is lower in lottery A, it is the safer alternative. The two blocks contained 10 lines. With each line, the chance to win the high payoff was increased by 10%. In line one, the chance to win the high payoff is 10% and the low 90% percent, respectively. As probabilities are often not understood, a 10-sided dice were used to illustrate the chances.

The individual risk attitude is revealed by the number of choosing lottery A. This is the so called HLL-value. A HLL-value up to three indicates a risk-loving type, four the risk-neutral and more than four the risk-averse type. Extreme choices of never or only choosing lottery B are consolidated to one or nine, respectively. Choosing back and force between alternatives, we find that 33% of the participants gave inconsistent answers.

Trust game

The Berg, Dickhaut & McCabe (1995) Investment Game, also known as trust game, is a common measure for the trust and trustworthiness which has been applied in different contexts in developed and developing countries (Johnson & Mislin 2011).
The participants are endowed with 100 INR[1] and have to decide how much of this endowment he would send to a complete stranger. This is the so called first-mover decision. In the

[1] The exchange rate was 72 INR for 1 EUR

original setting, the receiver would need to decide how much of the tripled money he would pay back. This is known as the second-mover decision. The participant receives the money paid back by the stranger as the payoff. The first mover-decision is used as the trust variable while the second-mover decision is taken as the trustworthiness variable (Johnson & Mislin 2011).

RESULTS AND DISCUSSION

Figure 1 displays the average pumping hour choice per round of the four different treatment groups in the experiment. The dashed line indicates the point where the different management institutions were introduced and values set back to the initial level. The solid lines in figure 1 represent benchmark of idealized user types. These result from applying different solutions from solving equation (1) and (2) (see Suter *et al.* 2012).

In the baseline sequence, all four treatment groups lie between the myopic and the rational type. Graphically we can see that in the non-cooperative treatment, the change is marginal while the cooperative management institutions push response toward the rational type. Both exogenous management institutions however, push the behavior towards the optimal type. The Kruskal-Wallis test supports the impression. We fail to reject the Null that there is no systematic difference between all four treatment groups during round 1 – 5 (p-value = 0.8481). The Wilcoxon signed rank test fail to reject that there is also no difference between the non-cooperative institutional arrangements and baseline group (p-value = 0.3019) while for other three, the Null is rejected at the 1% significance level.

Table 1 shows the means of the socio-economic information of participants in the four different treatment groups. Most of the listed variables are self-explanatory while others need some explanation. Caste is differentiated between General Caste on the one hand, Scheduled Caste (SC), Scheduled Tribe (ST), and Other Backwards Castes (OBC) on the other hand and those who do not consider themselves to any of these castes. This differentiation captures socially and educationally disadvantages. The number of assets according to the SEC classification is used as measure of the purchasing power of the household (for more details see MSRI, 2011 for more detail). The behavioral types “myopic” and “optimal” where isolated from the choices made in the baseline sequence. It is the difference was less than one choice unit (i.e. less than half an hour of pumping) than from the idealized type.

Table 1: Summary Statistics

	(1)	(2)	(3)	(4)
	164	156	160	120
Transect	.4390	.5385	0.4750	0.4333
(0 =South; 1 = North)	-	-	-	-
SSI	.6430	.6580	0.6386	0.6259
	(.2190)	(.2041)	(.2200)	(.2163)
Age	43.06	47.33	42.15	46.52
	(14.24)	(16.04)	(14.45)	(14.86)
Household Size	4.73	(4.83)	4.55	4.88
	(2.13)	(2.12)	(2.17)	(2.32)
Sex	.6503	.6623	0.5875	0.5763
(0 = Female/1 = Male)	-	-	-	-
Education	6.30	5.83	6.89	6.00

(Years)	(5.09)	4.88	5.01	6.37
Number of Save choices	5.56	5.23	5.82	5.59
	2.40	2.74	2.55	2.44
Farming	.7744	.7051	.6352	.7750
(0 = No/1=Yes)	-	-	-	-
Trust Game	30.88	30.76	35.09	30.57
(First Mover Decision)	(24.07)	(25.56)	(25.54)	(25.99)
Caste SC/ST/OBC	.5	.4615	.4312	.5
(0 = No/1=Yes)				
Land Holdings	11.30	11.03	12.41	9.92
(Acres)	(24.89)	(19.73)	(38.65)	(16.61)
Owning Borewell	.3293	0.2564	0.2375	0.2667
(0 = No/1=Yes)	-	-	-	-
Assets	5.76	5.60	5.55	5.40
(SEC Classification)	(1.45)	(1.65)	(1.71)	(1.70)
Myopic	0.3171	0.3846	0.3875	0.3583
(0 = No/1=Yes)	-	-	-	-
Non-Myopic	0.0793	0.0962	0.1188	0.1083
(0 = No/1=Yes)	-	-	-	-

(1) Cooperative (2) Supportive Exogenous (3) Restrictive Exogenous (4) Non-Cooperative

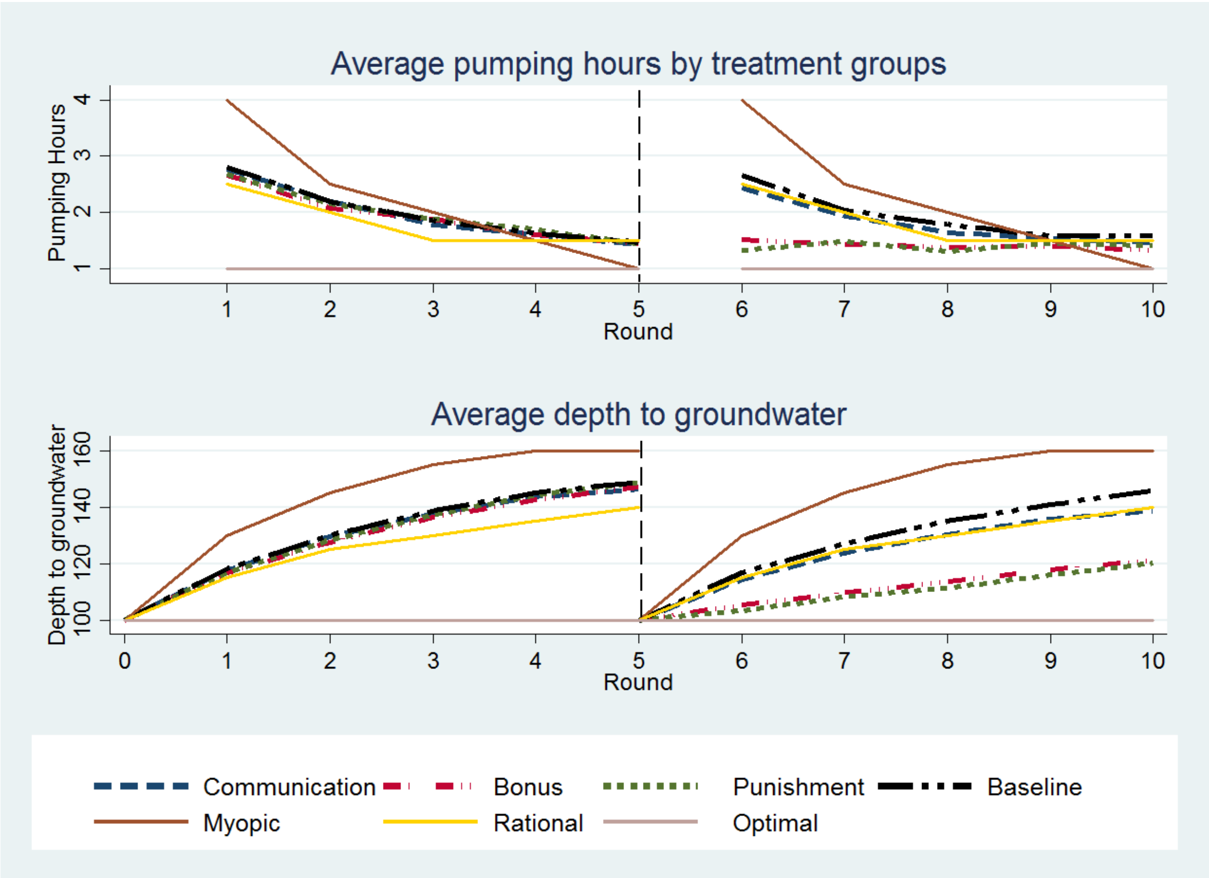

Figure 1 Average pumping hours (above) and average depth to groundwater (below) by treatment groups

The dependent variable on the choice variable “pumping hours” is discrete and ordered and the underlying model variable “water applied” is continuous but latent. The ordered probit approach is an appropriate model to account for both characteristics. For the analysis, clustered robust standard errors at the group level were computed because choices and outcomes within one group are not independent. In total 150 groups participated in the experiment. For comparisons only the second “treatment” sequence was used. As was already shown above, non-cooperative management institutions do not lower significantly the pumping rate.

The results of model (1) in table 2 show that both exogenous institutional arrangements have a significant negative effect at the one percent level on reducing the water consumption while the cooperative management institution also alters the behavior of the participants but is only significant at the 10% level. The magnitude is lower than for both exogenous management institutions. Considering the full model (2) and (3), the cooperative management institution becomes insignificant above the 10% level. The results of the regression are opposed to our expectations that cooperative management institutions reduce the water consumption the most. However, this observation goes along with the observation, that the trust game coefficient is negative and significant at the 10% level. These results do not change in model 3 where different behavioral types as explanatory variables are introduced. This finding supports the literature which underlines the importance of trust and supports the argument that exogenous management institutions can crowd-in cooperation if payoffs are only made privately.

Puzzling is that both exogenous management institutions are highly significant with comparable magnitudes. One explanation is that both institutions manage to have a supportive group effect, overcoming coordination problems.

Table 2: Results

	(1)	(2)	(3)	(4)
Bonus	-.8603***	-.8411***	-.8381***	-.5704**
	(.1259)	(.1156)	(0.1151)	(.2654)
Punishment	-.8506***	-.8681***	-.8558***	-.9652***
	(.1117)	(.1077)	(0.1083)	(.2742)
Communication	-.1978*	-.1644	-.1496	-.3783
	(.1057)	(.1039)	(.1017)	(.2788)
Transect		.4156***	.3963***	.3982***
(0 =South; 1 = North)		(.0875)	(.0867)	(.0845)
SSI		-.6024***	-.5715***	-.6364*
		(.2201)	(.2166)	(.3860)
Age		.0054**	.0055**	.0053**
		(.0026)	(.0026)	(.0026)
Household Size		-.0152	-.0151	-.0136
		(.0121)	(.0119)	(.0120)
Sex		.0019	-.0028	.0010
(0 = Female/1 = Male)		(.0605)	(.0600)	(.0601)
Education		.0184**	.0191***	.0192***
(Years)		(.0072)	(.0072)	(.0072)
Number of save choices		.0053	.0033	.0027
		(.0113)	(.0110)	(.0110)
Farming		-.0273	-.0186	-.0150

(0 = No/1=Yes)		(.0954)	(.0962)	(.0970)
Trust Game		-.0016*	-.0017*	-.0016
(First Mover Decision)		(.0010)	(.0010)	(.0011)
Land Holdings		.0006	.0004	.0005
(Acres)		(.0007)	(.0007)	(.0007)
Owning Borewell		-.0651	-.0688	-.0690
(0 = No/1=Yes)		(.0737)	(.0735)	(.0731)
Assets		-.0307	-.0309	-.0322
(SEC Classification)		(.0225)	(.0223)	(.0219)
Caste (SC/ST/OBC)		.1129*	.1019	.1066
(0 = No/1=Yes)		(.0629)	(.0626)	(.0628)*
No Caste		.6821**	.6696**	.6797**
(0 = No/1=Yes)		(.2823)	(.2767)	(.2760)
Myopic			.0725	.0635
(0 = No/1=Yes)			(.0799)	(.0775)
Non-Myopic			-.4977***	-.5277***
(0 = No/1=Yes)			(.1777)	(.1809)
SSIxBonus				-.4011
				(.4379)
SSIxPunishment				.1740
				(.4592)
SSIxCommunication				.3595
				(.4711)
N	3000	2755	2755	2755

Clustered Standard Errors in parantheses. Single, double, and triple asterisks (*, **, and ***) denote $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively

Interestingly, along the rural-urban interface extraction rates are more likely to increase with increasing urbanization. This effect is highly significant at the 1% percent significance level. The SSI index captures background processes which cannot be not entirely explained by the explanatory variables which have been introduced. One explanation might be that the city draws people which are mainly seeking short term economic opportunities rather than long term environmental benefits. Interaction effects of the different management institutions with the SSI are not statistically significant while the exogenous treatment variables still remain significant even though the significance level changes for the supportive cooperative institution and the SSI. Against our expectations, there is no clear better management institution in different stages of urbanization. The institutions seem to work in the rural as well as in the urban sites in the same way.

Considering the ecological background conditions, participants in the water-scarce northern transects are more likely to extract more than the relatively water-abundant southern transect. This result seems counterintuitive at first sight but reflects the situation of the people in the northern transects. Either they behave selfishly or the resource is taken by others. This results is in accordance with experimental findings from Castillo *et al.* (2011) and Prediger *et al.* (2011). The latter also shows that participant whose real life economic activity depends on the resource behave more selfishly in the experiment.

Risk attitudes do not seem to effect the decision making when it comes to water usage. This is in accordance with the literature and what we expected. The same holds for the user type. Those who behave close to the optimal benchmark user would also reduce the extraction of the CPR regardless of the management institution type.

The finding that disadvantaged castes are more likely to extract more is challenging to interpret. One explanation might be that participants from the general castes are better off and therefore more patient. The assets variable is negative but not significant. On the other hand, cultural and religious considerations which are also captured in these variables might have played an important role.

Considering other socio-economic variables, education and age increase the likelihood to take out more water out of the aquifer. These findings underline that short-term profit maximization seems to be more important than the long-term usage of the resource.

CONCLUSION

The provision of water is a challenging issue with a growing and more prosperous urban population. Aquifers are getting more stressed and might be exhausted soon. At the same time, the groundwater users are in a social dilemma whether to maximize profits or to prolong the usage of a resource.

So far, the focus has been on the provision of water for the urban population but less with the consequences of urban development (McDonald *et al.* 2011). With this paper, we add to the discussion which management institutions are needed in order to prolong the use of a CPR and particularly groundwater in the context of urbanization.

Our results suggest that the status-quo will lead to a rapid decline in groundwater as people tend to behave ignorant and myopic. In accordance with the literature, non-cooperative institutions are therefore not improving the life of the CPR. However, cooperative management institutions do not make the use of the CPR more sustainable which we would expect from the literature (Madani & Dinar 2012a, 2012b). On the other hand, enabling and restrictive exogenous institutions are very efficient in prolonging the life of the CPR. These results hold for rural as well as for urban areas.

We haven't evaluated combined management schemes which would be a further step in the analysis of CPR and urbanization.

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APPENDIX 1

Table: Variables and Parameters

Symbol	Label	Value	Unit
Variables			
X	Quantity of groundwater pumped		100000 ft³
π	Profit		INR
d	Depth to groundwater		Ft
Parameters			
α		180	INR
γ		2	INR
ϕ		1	INR
r	Recharge rate	40	100000 ft³
A		10000	Ac
S	Storativity	918274·10^-4	-