Does water scarcity lead to overuse? Evidence from field experiments

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Abstract:

The increased variability in rainfall patterns due to external shocks such as climate change can lead to different adaptive actions by socio-economic agents. This paper presents the results from an economic field experiment aiming to explore the responses of rural users of Colombia to exogenous changes in the availability of water resources. Subjects participated in a within-subjects common pool resources experiment with scarcity treatments. In the first stage of the experiment all subjects played with an abundant size of the resource, a baseline treatment. In the second stage a weak scarcity and strong scarcity treatments were introduced. In these treatments the experimentalists exogenously reduce the resource available from the baseline treatment in one third for the weak scarcity and two third for the strong scarcity. In a third stage, we generate an additional change in the resource availability whereby some subjects in the weak scarcity pass to a strong scarcity level. Our results suggest that users' response to weak scarcity shocks are ambiguous, but strong scarcity shocks result in increased levels of appropriation of the resource, closer to Nash predictions. These results support that severe water scarcity associated to climate change scenarios can entail an increase in extraction levels by water users, reinforcing the potential environmental damages and welfare effects of droughts.

Keywords: Water, CPR Field Experiments; Scarcity.

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1. Introduction

Extreme water events such as the occurrence of droughts or floods can be associated either to social phenomena (e.g. overexploitation of hydrological resources or human constructions in floodplains), ecological phenomena (such as changes in rainfall patterns) or the interaction between these two factors. There is strong evidence that rainfall changes are taking place at both global and regional scales (De Luís et al. 2000); however, we do not have enough knowledge about the way economic agents respond to those changes as well as the ultimate impact on the environment.

Ecological phenomena are out of direct short-term control of individuals or institutions. However, socio-economic agents can do much to reduce risk exposure to those phenomena, by protecting water providing ecosystems and conserving buffer stocks (e.g. in groundwater), and also crafting socio-economic institutions that help overcome the social dilemmas the ecological shocks may create. Depending on the extent, magnitude and direction of the ecological changes use patterns may vary (Janssen and Anderies 2007,Spenceley and Schoon 2007, Schoon and Cox 2010).

These changes may result either in reinforcing or mitigating the water problems, being droughts or floods. Most rivers worldwide are within watersheds under a great stress by human activities including development, dams, or extractive uses, which reduce their resilience to the impacts of climate change (Palmer et al. 2008). Palmer et al (2009) present an overview of the predicted impacts of climate change on river ecosystems that may be exacerbated by anthropogenic stressors. We focus on one of the most relevant of these interactions according to the authors: the exacerbation of droughts driven by climate change as a result of an increase of water extractions. Since climate change is likely to reduce the return period of drought events, the relevance of drought management will further increase in the future (Merrett 2004).

Uncoordinated responses to droughts by individual users can result in an aggravation of the tragedy of the commons, acceleration of resource depletion and the emergence of social conflict. Alternatively, coordinated responses to water scarcity shocks may avoid the over-extraction of the resources and social conflict. Scarcity crises have been posited as an important factor for collective action to emerge in scenarios of uncoordinated use of natural resources (Ostrom 1992, 1999). In addition, some scholars suggest that proactive policies that understand extreme fluctuations of water availability as a fundamental trait of river systems, can respond better to droughts (Palmer et al. 2009). Previous research has addressed the relevance of land planning (e.g. Palmer et al 2008) and economic instruments (e.g. Gracía-Vila et al. 2008, Merrett 2004), but has so far ignored users' response to scarcity.

This paper analyzes how direct users of a watershed in rural Colombia behave in a framed[1] common pool resource experiment when confronted to changes in the levels of the resource, in this case water. More precisely, we aim to assess if shocks in the availability of water have an effect on users' behavior in settings where the game theory prediction is that this does not affect the Nash or social optimum. In doing so, we contribute to a recent literature stressing the need

[1] According to Harrison and List's (2004) taxonomy our experiments are framed field experiments because the experiment simulates an occurring natural resource dilemma and our subjects are engaged in activities extracting water in the watershed.

to integrate the study of contextual variables, particularly ecological variables, into experimental studies (see Anderies et al 2011). Studies in this direction can capture closely the ecologic reality of participants in experiments, test the external validity of field studies as well as increase the relevance of behavioral experiments (Cardenas et al forthcoming, Janssen 2010).

In the past, the economic literature has given little attention to the reaction of common pool resources users to different resource stock levels. One of the few studies addressing this topic is Osés-Eraso and Viladrich-Grau (2007). These authors explore subjects' extraction decisions in a modified common-pool resources game under different resource allocations. Their results suggest that individuals in a between-subjects experiment restrain their extraction levels when the resource is scarce. Particularly their results support that the lower the initial stock level, the lower the average appropriation level. The stock level also affects extreme behaviors as abundant resources increase the frequency of full-appropriation and decrease the frequency of zero appropriation strategies. Our experimental design is close to Osés-Eraso and Viladrich-Grau (2007); however, as opposed to their study, we undertake a within-subjects design where participants face different scarcity treatments. Subjects in their study were assigned to a specific treatment with a defined resource stock level, and this level remained constant during the whole experiment. In our design, resource stock levels for a given participant vary exogenously along the experiment. That is to say, participants experience variations in the resource stock levels along the game. In doing so, our objective is twofold. First we investigate whether users of natural resources change their behavior when resources become scarcer. And second, we examine if previous experience with shocks have an effect on users' behavior. This is particularly relevant when studying water resources, which availability varies yearly or between years in many regions of the globe.

By keeping the design static we diverge from previous studies that model resource availability endogenously to the game by means of dynamic models. Mason and Phillips (1997) introduce dynamic cost externalities into their design by allowing costs to be negatively related to the current resource stock, and making future stock levels depend on current resource extraction levels. These authors find very little tendency for players to cooperate in that scenario; however, they also find that, in the advent of complete resource depletion, subjects reduce their harvests sufficiently that the stock rebounds back to an acceptable, but still socially non-optimal level. Fischer et al. (2004) introduce stock size in an intergenerational common pool resource game where the stock available to each generation depends on the extent of exploitation by previous generations and on resource's growth rate. Their results also support that restrained resource use may not be sufficient for users to achieve the social optimum. Osés-Eraso et al.(2008) extend the game from Osés-Eraso and Viladrich-Grau (2007) by modeling resource scarcity in a CPR appropriation game both endogenously and exogenously including a dynamic dimension. In this dynamic setting the resource availability depends on the initial environmental characteristics of the common resource and on human-induced resource depletion due to users' appropriation patterns. Their results support that initial resource scarcity limits subjects' appropriation because it induces caution for the subsequent rounds among participants. However, despite the fact that subjects show a more conservative extraction behavior, they cannot prevent resource depletion in all cases.

Also, by conducting our experiment with actual users of water resources for agriculture and cattle in rural communities we aim to contribute to previous field experimental literature. Results obtained in field experiments with users who use common pool resources in their daily life activities do not confirm the laboratory findings on response to participants' changes in availability of resources with university students. To the best of our knowledge the only two studies incorporating variations in the availability of resources in the field are conducted by Maldonado and Moreno (2010) and Cardenas et al. (forthcoming). Maldonado and Moreno (2010) conducted a semi- dynamic common pool resource experiment with individuals from eight fishing communities in Colombia. Their results are more pessimistic than previous laboratory conclusions. Their findings support that players over-extract the resource when confronted with a situation of scarcity, even if this constitutes inefficient behavior from an economic perspective, thus exacerbating the tragedy of the commons and accelerating resource depletion. Cardenas et al. (forthcoming) report the results of three field experiments conducted both in Thailand and in Colombia. In two of the experiments, a "forestry game" and a "fishery game", current resource availability depend on past appropriation decisions. According to their findings, the dynamic effects of the forestry and fishery games imposed a difficulty for players, hindering their capacity to recover the resource to the initial high level. Thus, these findings support again a more pessimistic view of users' response to reductions in the availability of resources. However, results from dynamic games need to be observed with caution, as previous literature has shown that subjects have problems understanding that kind of games (Moxnes 1998). This is particularly relevant in field experiments in rural impoverished communities where education and literacy levels are low (Cardenas and Carpenter 2008, Lopez et al. forthcoming, Anderies et al 2011). Therefore, it could be claimed that the inconsistency of findings from laboratory and field experiments may be due to the complexity imposed by the dynamic game to participants with low literacy levels. However, it could be also the case that the results respond to participants in the field taking into account other aspects affecting their utility functions in addition to the monetary payoffs when making their decisions. To overcome the comprehension problems that a dynamic game may create, we present a within-subjects static design that simplifies the decision task.

More importantly, as oposed to previous experiments addressing scaricty of resources, by using the basic model in Osés-Eraso and Viladrich-Grau (2007), we can interpret subjects' responses to changes in the availability of resources in a cleaner way. Previous research (e.g. Maldonado and Moreno, 2010) interprets subjects' behavior as deviation from Nash behavior. In their model the two different resource stocks available represent two different CPR games (an abundant scenario and a scarce scenario) where the Nash equilibriums are calculated at different extraction levels. As a result, interpreting subjects' behavior as deviation from the Nash equilibrium (as these authors do) give some fuzzy results because the behavior of some individuals who do not change their extraction levels when the stock changes may be interpreted as the Nash prediction in scarce scenario for the solely reason that the Nash equilibrium varies from one scenario to the other (in their abundant scenario the Nash equilibrium is a corner solution whereas in the scarce scenario is an interior solution)..

The rest of the paper is organized as follows: Section 2 presents the experimental design. Section 3 contains the analysis of the data and describes the main results. In section 4 we conclude and expose some ideas for further research in this line of research

2. Experimental design

We follow the common pool resource model presented by Osés-Eraso and Viladrich-Grau (2007). In the experiment, we model the strategic decisions of a group of *n* users who can make use of a natural resource of total size K_0 in experimental currency units (ECU). In the instructions the natural resource was presented as a watershed. Each one of the *n* individuals, *i*, has an equal endowment *e* that can be invested in the extraction of the natural resource, or invested in a safe outside activity with marginal payoff α. Every unit invested in the extraction of the natural resource, x_i, where $x_i \in (1, e)$, yields *w* ECU for the agent, but reduces the common-pool resource by *c* ECU, while every point placed in the safe option yields α ECU for the agent, leaving the common-pool resource unchanged.

$$K_f(X) = K_0 - cX \tag{1}$$

where $c>1$, X is the aggregate group units invested in the extraction, $X = \sum x_i$, and K_f is the remaining units of the resource at the end of a round after extraction decisions by all agents have taken place. At the end of each round all remaining K_f units are evenly distributed among all *n* players. Therefore, payoffs for each player π_i depend on the vector of individual appropriators' investments in the resource $\boldsymbol{x} = (x_1, \dots, x_n)$.

$$\pi_i(\boldsymbol{x}) = wx_i + \alpha(e - x_i) + \frac{K_f}{n} \quad \text{, if } X>X^*\text{, where } w>0 \text{ and } \alpha>0 \tag{2}$$

In order to describe a social dilemma for the extraction decision of the common-pool resource we assume $(w - c) < \alpha < (w - \frac{c}{n})$. Investment in the common-pool resource, the watershed, is more efficient from the individual perspective, since marginal net benefit from extraction is higher than investment in the safe option ($\left(w - \frac{c}{n}\right) > \alpha$). At the same time, at the aggregate level investment in the safe option entails higher net benefits than investment in the common pool resource (α>(w-c)), and thus it is more efficient from the social perspective. In this game, the dominant individual strategy is full appropriation, $x_i = e$, while social efficiency requires a minimum level of resource extraction $x_i = 0$. Note that the level of the natural resource K_0 does not influence the incentive structure of agents. Both the Nash equilibrium and the social optimum are independent on the abundance or scarcity of the resource. The values for each parameter used along the experiment can be found in table 1.

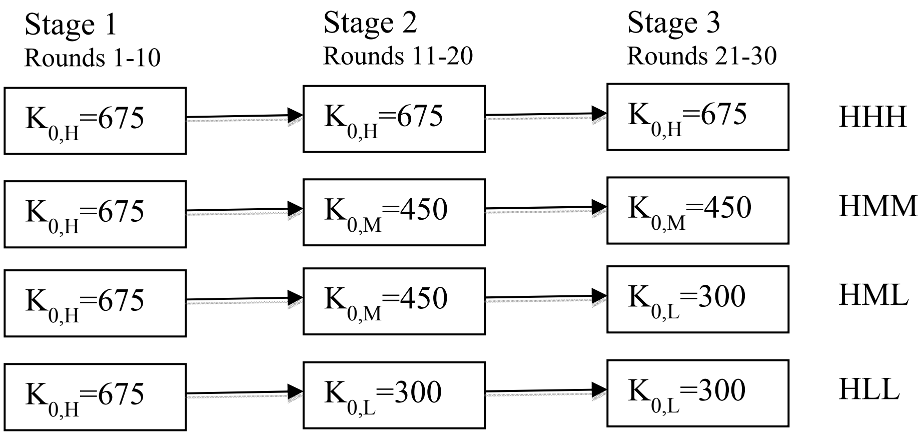
Table 1. Parameter values of the model for the experimental game.

Parameter	n	E	w	c	α
Value	5	20	2	3	1

The values of *w*, *c*, E and α follow the values presented in Osés and Viladrich (2007). The value of endowment of 20 units is chosen as a representation of the labor days in a month.

The experiment included four treatments, each treatment entailing three stages of 10 rounds. Figure 1 summarizes the different treatments we tested the water stock levels can be high (H), medium (M) or low (L), where M>M>L)

Figure 1. Scarcity shocks and resulting resource stock levels for different treatments.



As described before, during the experiment three water stock levels are evaluated: a high level (H), a medium level (M) and a low level (L). Subjects were placed to participate in one of the following treatments: HHH, HMM, HML and HLL, the first letter refers to the stock of the CPR for each stage (10 rounds) of the game. We set the level of water available in the low level $K_{0,L}$, so that when all players in a group extract their whole endowment, there is no resource left to be distributed among players ($K_f(100) = 0$[2]). This results in $K_{0,L}$=300 Thus, in the low level treatment, full-extraction by all users results in the exhaustion of the CPR. The initial state of the natural resource in the medium and high levels are arbitrarily defined as 30% higher than the immediately smaller level; $K_{0,M}$=450, and $K_{0,H}$=675. In table 2 we present a summary of the different resources levels we use in the experiment (high, medium and low), the Nash extraction prediction and the social optimum (in this case respectively 100 and 0 for all the resource levels). Additionally, table 2 includes the level of the resource at the end of the round if all the subjects in the group behave as the Nash prediction (K_f Nash) as well as if the level of the resource if all the subjects behave following the social optimum (K_f social optimum).

Table 2. Initial levels of the resource and final levels for group extractions in the Nash behavior and Social Optimum.

Levels	K_0	X Nash	X social optimum	K_f Nash	K_f social optimum
High	675	100	0	375	675
Medium	450	100	0	150	450
Low	300	100	0	0	300

A total of 20 sessions, evenly divided among the four treatments 5 per treatment, were conducted in different locations of the Coello watershed, Colombia, during the summer of 2010. The case of the Coello Watershed has been studied previously with different methods. Johnson

[2] This is aimed to avoid negative units of the resource to be distributed among players at the end of a round (which may be counter intuitive for users of water resources in real life).

et al. (2009) studied the importance of watershed resources in the livelihoods of the poor in the Coello Watershed and found that opportunities for reducing poverty through increased provision of water in the studied communities were relatively limited and that water scarcity and quality issues may be salient just for the households that are out of poverty. Cardenas et al. (2009) conducted an "irrigation game" field experiment in communities located along the Coello Watershed where participants had first to provide them-selves with the irrigation infrastructure (public good), and then extract one after the other the water for private consumption. The authors found that the sequential extraction in the irrigation game reduced cooperation, that willingness to provide for infrastructure was conditional on the extraction position of the player and that communication and external regulations increased cooperation.

In each session, we run the experiment with one or up to three groups of 5 subjects. Each session lasted about three hours. The recruitment process for these experiments was done with the help of leaders and NGO's working in the region. In the invitation, the experiments were presented to participants as a decision making activity. In order to have a diverse sample we invited all the inhabitants of the community who were older than 18 years old; however, in order to avoid some noise to the experiment, we did not allow people from the same household to participate in the same group. Once the group was completed we started the experiment by reading aloud the instructions. In the instructions we emphasized that the game was static, namely, that extraction level do not affect the water availability in the next round or stage. From this point on, subjects were asked to remain in silence for the whole experiment, if somebody had a question he was asked to raise his hand and ask the question to the experimenter in private. During the instructions, subjects were told that the experiment had three stages, each one of 10 rounds. After finishing the instructions, subjects were asked to seat back so that it was impossible for them to see other participants' forms. Next, several practice rounds were played in order to familiarize the subjects with the game, and the different forms. Field assistants helped subjects with reading and/or writing difficulties; however, participants with difficulties were required to make their own decisions and the assistant transcribed the decision into the game forms. During the three stages of the whole experiment subjects were not allowed to communicate or to use any other means to coordinate their actions.

In all stages of the experiment, each subject had to write down his decision in a "decision card" that was collected by the experimenter. Once the experimenter collected the decision cards from the whole group, he announced in public the total extraction of the group, the level of ECUs remaining in the watershed and the ECUs earned by each participant. (which was in all cases a fifth of the total ECU remaining in the watershed). Then, each individual was able to calculate his payoff in each round.

Table 3 presents some of the socio-demographic characteristics of the subjects Agriculture is the main economic activity (44% of the sample) followed by daily labor in farms (23%). The majority of subjects participating in the experiment are males (63%), with an average age of 44 years and slightly more than 7 years of education. Further, most subjects (76%) have been living in the area for more than 10 years.

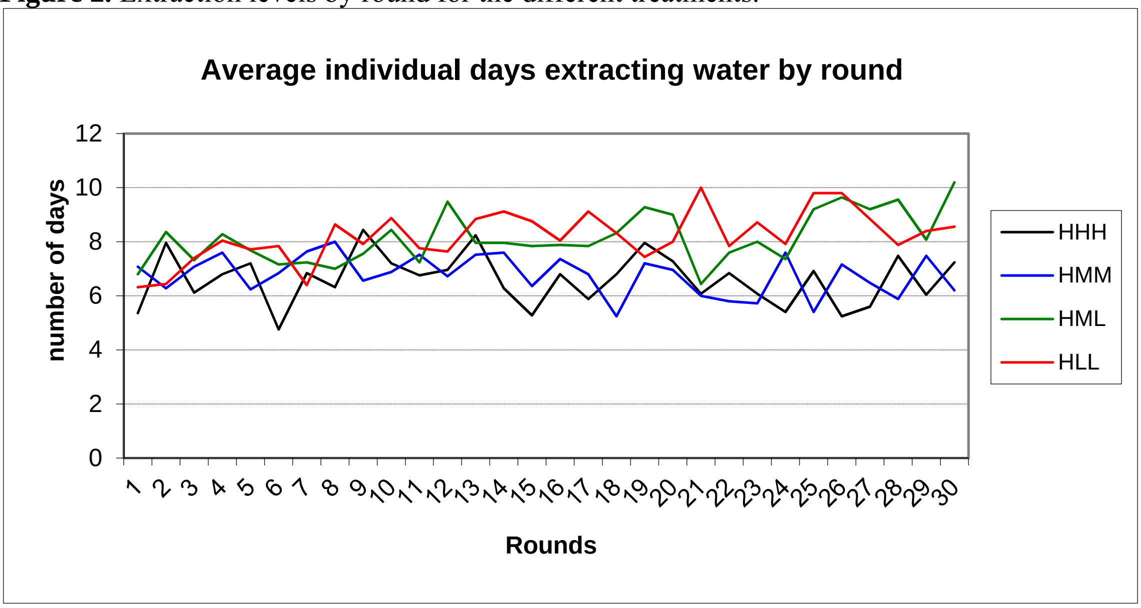
Table 3. Subjects' Socio-Economic Characteristics	
Number of participants	100
Percent Male	63
Mean age	44
Percentage of people living in the area for over 10 years	76
Mean years of formal education	7.48
Percentage of people who mainly live from agriculture	44
Percentage of people working for days	33

At the end of each session, while subjects were filling a socioeconomic survey, we calculated each person' earnings to be paid in cash. Individuals' earnings ranged between 8,322 and 18,037 pesos with an average of 13,218 pesos (about US $7.266 dollars[3])

3. Results

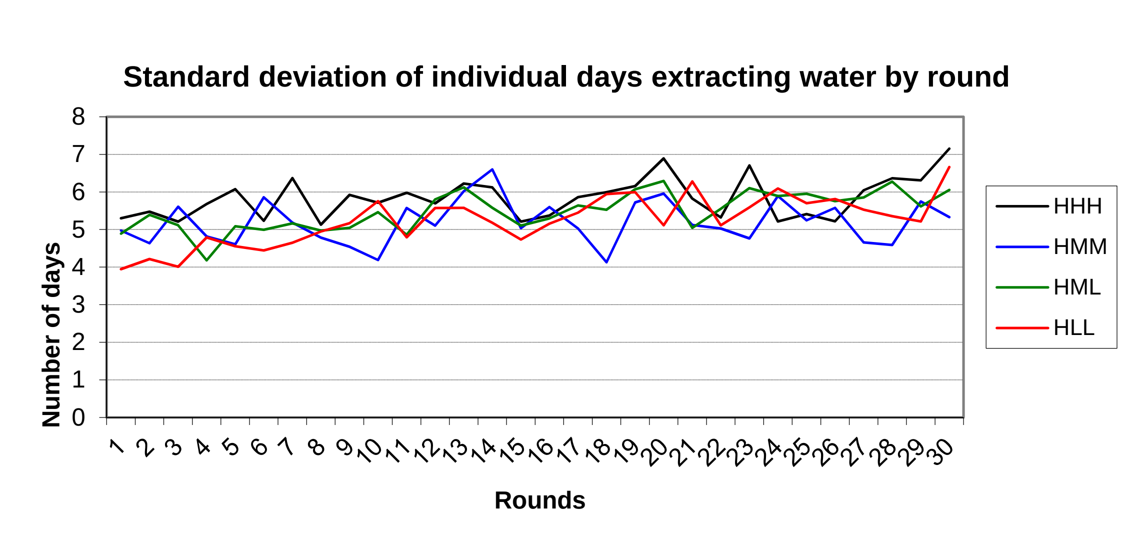
A first approximation to the data is provided in Figures 2 and 3 and Table 4. In Figure 2, we present a time series of average individual days extracting water from the watershed by treatment. Figure 3, illustrates the standard deviation of the individual days extracting levels. Table 4 contains the summary statistics by stage and by treatments. In the first stage of the experiment (round 1 to 10) average extraction levels is around 7.2 days in all treatments. Thus, consistent with previous findings in the field (Cardenas 2011, Lopez et al 2010, Cardenas et al. 2000) individual decisions without external regulations or communication (very often referred to open access in the literature) deviates from the Nash Equilibrium (extraction of 20 days), but it is also different to the social optimum (in this case 0 days)

Figure 2. Extraction levels by round for the different treatments.



[3] In August 2010 the exchange rate was for one dollar 1.819,06 pesos.

Figure 3. Standard deviation by round for the different treatments.



In stage 2 and stage 3 there seems to be some differences across treatments. Treatments HHH and HMM seem to be very similar in all the three stages. In the HML treatment, average extraction days seem to increase in stage 2 (medium level) and increase again in stage 3 (low level). In treatment ALL, average extraction days also increase from stage 1 to stage 2 and from stage 2 to stage 3 (8.3 and 8.8 respectively). These preliminary results suggest that the level of extraction varies once we vary the initial level of the resources.

Alternatively, standard deviations within each stage do not vary much across stages, nor across treatments (between 0.31 and 0.38), suggesting that the variability of individual decisions was relatively low and constant despite the occurrence of different scarcity shocks.

Table 4. Summary Statistics

Treatment	Average Extraction Days Stage 1		Average Extraction Days Stage 2		Average Extraction Days Stage 3	
HHH	6.7	(0.36)	6.8	(0.38)	6.3	(0.38)
HMM	7.02	(0.31)	6.9	(0.35)	6.4	(0.33)
HML	7.6	(0.32)	8.3	(0.36)	8.5	(0.38)
HLL	7.6	(0.30)	8.3	(0.34)	8.8	(0.37)

Standard deviations in parentheses

We continue the analysis by examining the differences between the different treatments in the different stages. The experiments created a panel data set with 100 unique subjects participating in a 30-round experiment, for a total of 3000 observations. We estimated the random effects Tobit model presented in equation 3:

$$x_{it} = \beta_0 + \vec{\beta}_1 \times treatmentsstage2 + \vec{\beta}_3 \times treatmentsstage3 + v_i + \varepsilon_{it}$$

(3)

Where x_{it}, are the individual water extraction level for each subject i=1,…,100 and each round t=1,…,30. The dependent variable is thus discrete between the range 0 and 20, both inclusive. The individual random effects are $v_i \sim N(0, \sigma_v^2)$ and $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$ is the idiosyncratic error term. The β_0 term captures average days extracting water during the first stage of the experiment for all treatment. In the first stage all groups played under a high level of the CPR and in a similar model, not reported in this paper, we found no significant differences across different treatments in the first stage. Results in Table 5 do not include socio-economic characteristics of participants presented in table 3 because an additional regression indicated that those characteristics do not seem to explain the individual water extraction levels. The results from the estimation are presented in Table 5.

Table 5. Random Effects Tobit Model of individual days extractions.

VARIABLES	Individual days extracting water
HHHstage2	0.0878
	-0.412
HHHstage3	-0.594
	-0.414
HMM stage2	-0.231
	-0.393
HMM stage3	-0.763*
	-0.393
HML stage2	0.741*
	-0.395
HML stage3	0.998**
	-0.395
HLL stage2	0.762*
	-0.389
HLL stage3	1.289***
	-0.389
Constant	6.900***
	-0.498
Observations	3000
Number of players	100

This econometric analysis enables us to present Results 1-4 about the effect of scarcity shocks on subjects' behavior in a CPR.

Result 1: The high level condition generates the same results across stages and treatments.

Table 5 shows that treatment HHH in stages 2 and 3 are not significant different from the stage 1. Additionally a Wald test[4] shows no difference between HHH in stages 2 and 3 ($\chi^2(1)=2.63$, $p=0.10$). That is to say, individual water extraction level is constant over time. This observation is consistent with findings from other common pool resources conducted in the lab and in the field (Cardenas 2011, Cardenas and Carpenter 2008, and Velez et al 2010). By establishing that this first observation is consistent with others in this literature, we can be confident that any changes in outcomes in the other treatments are due to treatment effects rather than some bias in the selection of our sample.

Result 2: The medium level condition does not have a clear effect on subjects' behavior

Subjects' exposure to medium level of the CPR has different effects on users' extraction decisions across treatments. As shown in Table 5, individual water extraction under medium levels has different significance and signs for different treatments and stages (HMM stages 2 and 3, HML stage 2) compared to the high level in stage 1. Individuals in stage 2 of treatment HMM do not extract statistically different number of days as respect to the extraction levels of all participants in the first stage (constant). However, extraction levels of individuals in the medium level of treatment HML in stage2 extract significantly more than individuals in the first stage and individuals in the second stage of treatment HMM (statistically different at the 10% level; p= 0.08).

When exploring the results for medium levels in the third stage we see that individual extractions in HMM in the last stage, medium levels, are statistically lower than extractions in the first stage of the game at the 10% ,but not statistically different to those of HMM in stage2 (also with medium levels). However, individual extractions in the last stage of treatment HMM are significantly lower than extractions in the second stage of treatment HML. Thus, despite being confronted to the same level of the CPR, individuals respond in different ways across treatments and stages.

In sum, a medium decrease of the size of the CPR does not seem to affect user's behavior unambiguously insofar the increased scarcity does not threatens the survival of the CPR.

Some of the possible explanations of these differences may come from differences in the distributions between treatments HMM and HML in the second stage, which are significantly different at the 1% with a Kolmogorov-Smirnov test for differences in distributions. However, these remain so far unexplained. We have tried different explanatory variables that may control for differences in the level of extraction from the CPR between different treatments, including socio-economic characteristics, fixed effects for location where the experiments were conducted and round effects. None of these appear to be significant in explaining variability of behavior under medium levels of the resource.

[4] All statistical analyses between average extraction days for different treatments are presented based on Wald tests.

Result 3: In the condition where it is possible to fully deplete the CPR (low level), subjects extract more

Results from Table 5 show that individual extraction levels in stage 2 of the HLL treatment, are significantly higher at the 10% level than extraction levels in the baseline scenario. Furthermore, in stage 3, this race for the scarce resources is maintained, with average extractions in the third stage of HML significantly higher at 5% than the baseline and at the 1% for the third stage of HLL.

When comparing HLL in stage 2 and stage 3 we see that the average extractions are not statistically different. Then, our results support that prolonged exposition to strong scarcity levels does not further increase average extraction levels.

Comparing Result 2 and 3 we could suggest that levels of the CPR, which do result in the exhaustion of the resource with full appropriation by users, generate mixed responses among participants whereas when the resource can be exhausted, participants unambiguously increase their extraction levels.

Result 4: Previous experiences with a change in the level of the resource, do not affect subjects behavior in low level condition.

This result derives from the fact that there is no statistically difference between HML and HLL in stage 3. This is an interesting result because it shows that subjects' response derives from the level of the resource, being in this case low, and not on the path that has lead to that level (direct shift from high to low in HLL or with an intermediate level in stage 2 for HML).

In sum, these findings contribute to the understanding of users' behavior when exposed to several changes in the stock level of a CPR. First our results complement the economic theory by suggesting that individuals behave differently under different resource availabilities and that a threat of exhaustion of the resource is necessary to generate consistent behavior among users (Results 2 and 3). Our within-subjects findings, as opposed to Osés-Eraso and Viladrich-Grau (2007) between-subjects results, support that when users are aware that the resources are becoming scarcer they increase their extraction levels. Second, it appear to be the level of the resource which is important and not previous experimences with exogenous changes in the size of the CPR (Result 4).

X. Conclusion

In the past decades the experimental economics literature in environmental and development issues had generated very valuable and interesting results that covers issues from economic valuation to the creation of economic incentives (see Sturm and Weimann 2006, Cherry et al 2007, Cardenas 2011 for a literature review). In the studies related to resource management the focal point of attention have been how to solve the social dilemmas incurred by the use (or the provision) of the resources keeping the ecological characteristics of the resources understudied. In this paper we attempt to address this question by conducting a common pool experiment where subjects face different levels of resources in different stages of the experiment.

In our study, we analyze how direct users of a watershed in rural Colombia behave in a framed common pool resource experiment when confronted to different levels of the resource. More precisely, we explore whether shocks in the availability of water have an effect on users' behavior and if previous experience with shocks have an effect on users' behavior. Our findings seem to support that the relationship between scarcity shocks and resource extraction patterns depend on the extent of the scarcity shocks. When the resource becomes scarce but resource conservation is still guaranteed, users do not react consistently across the board; in some treatments subjects extract less than in the abundant treatment and in other treatments they extract more. Alternatively, scarcity shocks that put in jeopardy the resource conservation seem to consistently result in an intensification of uncooperative strategies. cause resource exhaustion. This result contrasts with previous between-subjects findings in the lab (Osés-Eraso and Viladrich-Grau 2007) and is consistent with semi-dynamic field results (Maldonado and Moreno 2010).

Furthermore, our analysis supports that it is the low level of resource availability, and not previous experiences with exogenous changes in resource availability that drives subjects' behavior. Frequency of experiences has been related to learning, the emergence and maintenance of cooperation (Ostrom, Gardner and Walker 1994) and policy effectiveness (Bennett and Howlett 1992). Our results are not necessarily opposed to that theory. In our experiment, changes in the level of the resource were exogenous to participants, thus, they had no way to relate these changes in the resource to their behavior.

Our results raise some immediate questions about the resource level generating subjects' consistent changes in behavior. In this vein, a subsequent question is what factors affect the direction of resource extraction changes when resource stock levels decrease. Is the fact the resource can be depleted in low level condition what drives subjects change in behavior as respect to the high level? Or, it is because the payoff differential between the high and the low level conditions fosters rent seeking (or free riding) behavior?

Other open questions for further research include, to mention a few, the effect of communication, uncertainty and other contextual variables in subjects' response to scarcity chocks. The positive relationship between communication and cooperation in CPR games is well proven, but it is unclear if the impact of communication would be affected by scarcity shocks in CPR games. Put it another way, if changes in resource stock levels will affect the willingness of resource users to communicate in CPR games. Also, despite initial steps in understanding users' reaction to changes in water availability, the scholarship does not address how risk and time preferences influence users' extraction behaviour under uncertainty on future availability of the resource. Most empirical and experimental applications assume that subjects are risk neutral and have homogenous time preferences Thus, these studies do not take into consideration that risks and time preferences may influence the way user's make decisions about their extraction patterns in contexts of increased risk of future droughts.

In addition, these studies do not explicitly consider that the decisions of water users depend also on many technical, social, economical, policy and environmental constraints. These constraints vary from place to place according to land vocation, access to water rights, water tariffs and availability of irrigation infrastructure in such a way that large scale or aggregated model might be uninformative about the driving forces behind water demand. The methodological alternative to use local and low scale model requires detailed information, which is not always available, and furthermore their results might not be easy to generalize or aggregate.

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