UNIVERSITY OF CALIFORNIA
UC RIVERSIDE
School of Public Policy

UCR SPP Working Paper Series

August 2016 – WP#16-05

TABLE OF CONTENTS

Alternative Policies to Manage Electricity Subsidies for Groundwater Extraction: A Field Study in Mexico

Edgar Tellez Foster, Amnon Rapoport & Ariel Dinar
Environmental Sciences, School of Business Administration, School of Public Policy,
University of California Riverside

Summary:

We designed a series of field experiments to study the behavior of farmers under alternative electricity subsidies for extracting groundwater. Users' water pumping decisions are based on the price of electricity, level of subsidy, and height of the water table. The paper opens with a brief description of common pool resource dilemmas and the value of field experiments in the analysis of such issues. It then describes the model used to draw predictions. We analyze the theoretical effectiveness of three policy interventions: elimination, reduction, and decoupling—an innovative policy that substitutes the electricity subsidy for a cash transfer. Results from the experiments conducted in the city of León, Guanajuato, México, suggest that all three policy interventions sustain positive effects on the pumping level: Elimination has the largest effect, whereas reduction results in only a marginal effect on the rate of water extraction. Decoupling proves to be a viable policy, as it produces an effect similar to elimination while avoiding political and social damage. We then compare these results with lab experiments conducted in the United States.

Acknowledgements: This research was funded by the Center for Behavioral and Experimental Agri-environmental Policy Research (CBEAR). Tellez Foster would like to acknowledge UC Mexus-Conacyt. Dinar would like to acknowledge the Hatch Project W3190, "Management and Policy Challenges in a Water-Scarce World," for its support.

Introduction

Most natural common pool resource (CPR) dilemmas are intertemporal and subject to environmental uncertainties. Examples include groundwater, fishery resources, and climate change, all of which are dynamic in size and duration. CPR size may change over time in part as a function of previous user appropriation (Bailey et al., 2010; Barrett & Dannenberg, 2012; Koundouri, 2004). The uncertainty about the duration of the dilemma may be endogenously or exogenously determined, or both. The analysis of strategic behavior in the face of environmental uncertainty traditionally has been conducted under the assumption of single-period interaction (e.g., Budescu, Rapoport, & Suleiman, 1995; Rapoport & Suleiman, 1992), whereas the analysis of strategic behavior in time-dependent settings has ignored environmental uncertainties altogether. Dynamic models, which integrate these two dimensions, have been proposed and tested experimentally by Herr, Gardner, and Walker (1997), Mason and Phillips (1997), and Botelho, Dinar, Pinto, and Rapoport (2015).

Our proposed study of groundwater extraction in a dynamic setting differs from previous studies in three ways. First, the intertemporal uncertainty we embed in the CPR setting concerns the duration of the groundwater game rather than the size of the common pool (which is determined exogenously in our study). Second, rather than focusing exclusively on laboratory experiments, we propose conducting both a laboratory study in the United States and a comparable field study with farmers in Mexico. The third and most important difference is that our study is heavily policy oriented. It intends to examine the behavioral responses of profit-maximizing users, whether these are students volunteering for CPR laboratory experiments or farmers regularly pumping groundwater for irrigating their fields, to the proposed systematic modifications of the electricity subsidy mechanism for groundwater extraction.

Electricity subsidies for pumping irrigation water is common in many countries around the world (Shah, 2009, p. 148–150). In Mexico, the focus of the present study, a total volume of 29.5 km^3 is extracted annually from groundwater resources. Of this amount, 70% is used in irrigated agriculture. The Mexican government decided in the early 1990s to provide a subsidy, Tarifa 09, for electricity used in pumping water for irrigation. The subsidy (pesos/KwH) is provided to farmers based on electricity used. The subsidized pumping cost has led to mismanagement practices and lack of appropriate irrigation technology, causing 101 out of the 188 major aquifers in Mexico to be over drafted (Muñoz et al., 2006). According to the Mexican National Water Law, water used for irrigation is not priced, so farmers have to pay for the cost of extracting groundwater from aquifers only. The current institutional framework with no price that reflects the scarcity value of the water pumped leads to inefficient exploitation of groundwater resources with high social damage.

The CPR dilemma has been studied using normative game-theoretical perspectives by introducing models developed to explain and predict social outcomes, given the environmental and institutional contexts. The dilemma also may be studied from the experimental perspective, in which the environmental and institutional contexts are simulated and the predictions of user behaviors (based on a normative model) are tested. There is a concern about conducting experiments in the lab since they restrict our sample to university students, who constitute a highly-selected group in terms of age, socioeconomic status, educational background, and experience. Therefore, variations between the results of controlled experiments in the laboratory and the results of field studies may exist due to differences in subject population, culture, and experience.

Several field experiments on CPR dilemmas have been conducted in the past, all of which are relevant to our work. The following paragraphs provide a brief review of these works.

Cárdenas (2011) addressed the importance of field experiments by conducting a series of experiments with a mixed population that mostly consisted of participants in the field but also of college students in the lab, where they participated in exact replications of the field experiments. His experiment addressed a common CPR decision problem with a negative externality in consumption. He found that behavior in both lab and field experiments did not change substantially, and any differences between the two subject populations that did occur were due to the fact that participants in the field and in the lab bring their own personal experience to the game. Cárdenas's (2011) comparison of subject populations in experimental and field studies illustrates the value of testing a policy change in the field with stakeholders, as this offers sound, replicable, and reliable insight into the policy's potential effects on convenience and cost effectiveness.

There exists a large body of literature on experiments in the field. Velez et al. (2005) explore exploitation of CPRs with a series of experiments in the field. They found that subjects balance self-interest and conformity in selecting the average strategy. Salcedo et al. (2013) conducted a series of experiments about how cooperation could help reduce the amount of groundwater pumped in the state of Aguascalientes, Mexico, and they found that differences between the theoretical predictions and the outcomes from the experiments exist due to the fact that some subjects act irrationally or take into account other factors that increase the costs of pumping. Cárdenas (2011) analyzed the social norms and behavior in CPR settings using data from field experiments that he conducted in Colombia, and Cardenas and Ostrom (2004) explored cooperation in common with experiments conducted in Colombia as well. The first compares results from field experiments with replications of the experiments conducted among students in a laboratory setting in Colombia. The general results suggest that differences in behavior may be accounted for in the subject's experience that is brought into the lab and influences decisions.

Ward et al. (2006) demonstrated the relevance of conducting experiments both in the field and in the lab. They claimed that the environmental and institutional conditions could lead to different results. They conducted lab and field experiments, evaluating different institutional arrangements for water administration, and concluded that different arrangements work better in the lab than in the field. Therefore, researchers must take into account different institutional arrangements, social norms, group reputation, and social connections to better translate experimental results into policy.

This study seeks to explore the effects of modifications to a subsidy mechanism on users' behavior concerning pumping rates, and, as a consequence, on the status of an aquifer over time. Using field experiments, this paper investigates how farmers change their behavior when they face policy interventions, including: complete elimination of the subsidy, reduction of the subsidy, and decoupling the subsidy from its volumetric nature and substituting it with a lump-sum subsidy calculated on the basis of the average subsidy received in a predetermined number of previous periods. The data collected from these field studies allow the evaluation of the impact the policy interventions have on the groundwater pumped from the over drafted aquifers, which should help in proposing the implementation of policies with stakeholder feedback.

Theoretical Model and Predictions

We follow the Tellez Foster et al. (2016b) model, in which an intertemporal optimization problem is presented with a dynamic equation of motion representing the height of the water table over time. Because a more detailed exposition of the model is presented in Tellez Foster et al. (2016b), we present below a reduced form of a normative model followed by theoretical predictions.

The benefit function below is based on the simplifying assumptions of a box-shaped bathtub aquifer shared by homogenous, single crop farmers; it is inspired by similar models introduced by Provencher and Burt (1993) and Salcedo and Gutierrez (2013). The benefit function for pumping groundwater for farmer *j* in time *t* is:

$$B_{jt} = \delta u_{jt} - u_{jt}\left[\frac{\gamma P_E \xi}{(\bar{X}-x_t)AS}\right] - C_0, \qquad (1)$$

where δ is the constant marginal product of water extracted u_{jt}, γ is the subsidy to electricity for pumping groundwater, P_E is the price for electricity, ξ is the amount of electricity required to pump one cubic meter of water to a height of one meter, $\bar{X}$ is the maximum depth of the aquifer, x_t is the height to water table in time *t*, A is the area of the aquifer, and S is the storativity. AS is the available volume of the aquifer that can store water, and C_0 is the fixed cost of pumping, generally associated with installing and maintaining pumping equipment, which, for simplifying purposes, are assumed as zero.

The motion equation of the water table is:

$$x_{t+1} = x_t + \frac{\sum_{j=1}^{N} u_{jt} - R}{AS}, \qquad (2)$$

where the height to the water table in the next period, x_{t+1}, is equal to the current height plus the amount of water pumped in the current period, $\sum_{j=1}^{N} u_{jt}$, minus the recharge rate R, all divided by the area multiplied by the storativity. The dynamic optimization problem for the entire aquifer is then described by:

$$\max_{u_t} \sum_{t=1}^{\infty} a^t J \left[\delta J u_t - u_t \left(\frac{\gamma P_E \xi}{(\bar{X} - x_t) AS} \right) \right] - C_0$$

$$s.t. \qquad \begin{aligned} x_{t+1} &= x_t + \frac{J u_t - R}{AS} \\ x_t + \frac{J u_t}{AS} &\leq \bar{X}, \end{aligned}$$

where J is the number of users in the aquifer.[1]

---

[1] Given that we assumed previously that all farmers are homogenous, the *j* subscript is dropped.

This model was simulated to obtain predictions in three policy interventions (elimination: $\gamma = 1$, subsidy level of 0%; reduction: $\gamma = 0.5$, subsidy level of 50%; and decoupling: $\gamma = 1$, subsidy level of 0% and cash transfer equivalent to the average subsidy received in the previous i periods) using the parameters used by Salcedo and Gutierrez (2013) that are presented in Appendix A.

The following Bellman equation is derived from the above optimization model and is used recursively to simplify the optimization problem by breaking it down into a two-stage function that is used to calculate the optimal path of extraction:

$$V(x_t) = \max_{u_t}\left[J\delta u_t - u_t\left(\frac{\gamma P_E \xi}{(\bar{X}-x_t)AS}\right) - C_0\right] + \alpha V[x_{t+1}]. \qquad (3)$$

The first order conditions yield the following Euler equation:

$$J\delta - \frac{\gamma P_E \xi}{(\bar{X}-x_t)AS} = -\alpha\left[\frac{J u_{t+1}}{(\bar{X}-x_{t+1})AS} - \lambda\right]\frac{J}{AS}\,, \qquad (4)$$

where

$$\lambda = \frac{J\delta - \left(\frac{J\gamma P_E \xi}{(\bar{X}-x_{t+1})AS}\right)}{\frac{J}{AS}},$$

where we observe that changes in the value of $\gamma \rightarrow 1$the costs in the current period by increasing the value of the numerator in $\frac{\gamma P_E \xi}{(\bar{X}-x_t)AS}$ and simultaneously increasing the discounted benefit of extracting one extra unit in the future (λ) leading to a likely decrease in the extractions for every period that will yield a less deep steady state value for the height of the water table.

Policy Interventions

After establishing the theoretical framework of the optimization problem, we analyzed a set of policy interventions to be tested in the field. Using the parameters from Salcedo and Gutierrez (2013), presented in Appendix A, we simulated the model for 100 periods, varying the value of γ from 0 to 0.8 in increments of 0.1 to analyze the behavior of the water users and its impact on the pumping and height to the water table as a function of the level of subsidy. Figure 1 demonstrates that there is a steady increase in the height of the water when the level of subsidy increases, thereby demonstrating that there is a strong connection between the state variable and the level of subsidy.

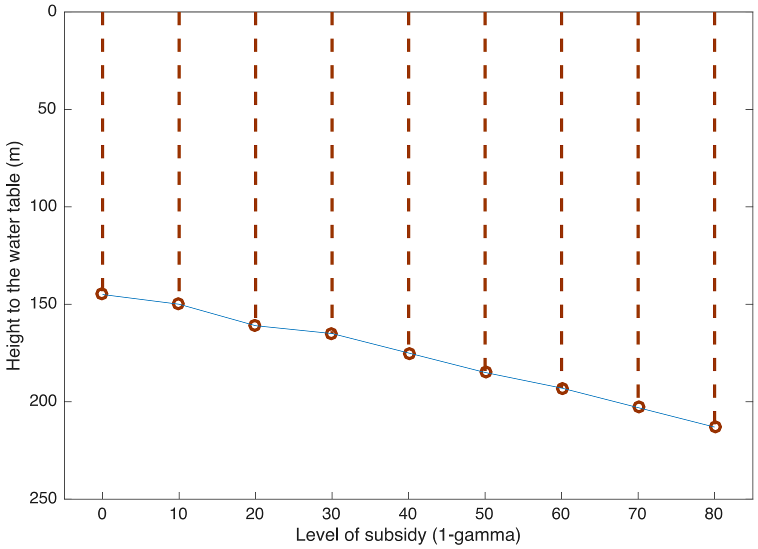


Figure 1. Relationship between level of subsidy and height of the water table.

For our analysis, we focus on four scenarios: Status quo ($\gamma = 0.2$), reduction ($\gamma = 0.5$), elimination ($\gamma = 1$), and decoupling the subsidy ($\gamma = 1$ and a cash transfer equivalent to the average subsidy received in the past i periods). In the latter case, the optimization problem is updated to include the decoupling factor, and it is represented by:

$$\max_{u_t} \sum_{t=1}^{\infty} a^t J \left[\delta J u_t - u_t \left(\frac{\gamma P_E \xi}{(\bar{X} - x_t) A S} \right) \right] - C_0 + \phi \,, \quad (5)$$

where

$$\phi = \frac{\sum_{k=t-i}^{t} \frac{u_k \gamma P_E \xi}{(\bar{X} - x_k) A S}}{i} \,.$$

In comparison with Equation 3, with the respective Bellman equation, we obtain:

$$V(x_t) = \max_{u_t} \left[J \delta u_t - u_t \left(\frac{\gamma P_E \xi}{(\bar{X} - x_t) A S} \right) - C_0 \right] + \phi + \alpha V[x_{t+1}]. \quad (6)$$

In this case, the decoupling factor $\frac{\sum_{k=t-i}^{t} \frac{u_k \gamma P_E \xi}{(\bar{X} - x_k) A S}}{i}$ is calculated for all $t \in [1, i] \; \forall \; i > 1$.

The hypothesis tested in the field experiments predicted that changing the subsidy structure by eliminating the subsidy, reducing the subsidy, or giving users a transfer equivalent to the average subsidy they received in past periods would result in a decrease in the individual requests that lead to a higher steady state of the height to the water table.

Figure 2 portrays a comparison between status quo, subsidy reduction from 80% to 50%, and decoupling with a 15-period lag for calculating the average decoupling factor.[2] Decoupling accomplishes the highest steady state of the height of the water table, which suggests it to be a viable policy intervention.

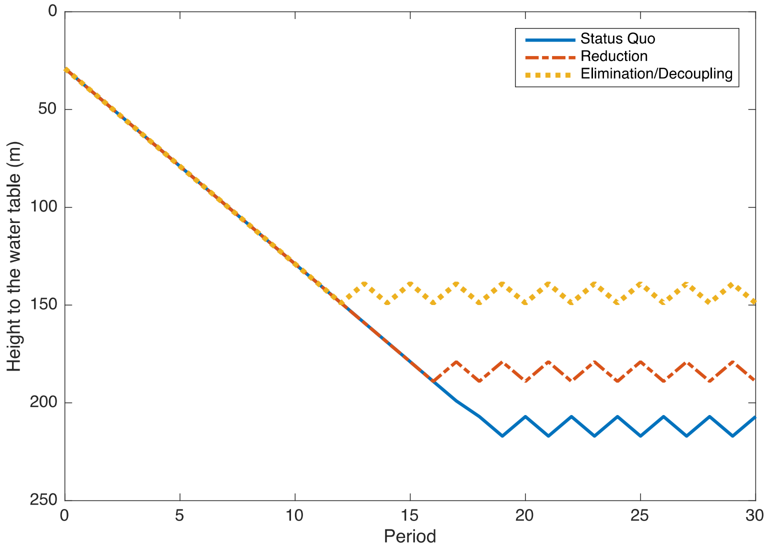


Figure 2. Steady state of the height of the water table under different policy interventions.

We observe that the steady state forms a periodic wave rather than a horizontal line; this is explained by the extraction path, where after reaching a certain depth, the users change from extracting zero units to extracting 10, as shown in Figure 3.

---

[2] The results for the elimination scenario are exactly the same as in the decoupling scenario, since in the optimization problem, the decoupling factor (which is a constant) is dropped from the first order conditions. For a more detailed explanation of the choice of the length of the lag, please refer to Tellez Foster et al. (2016a).

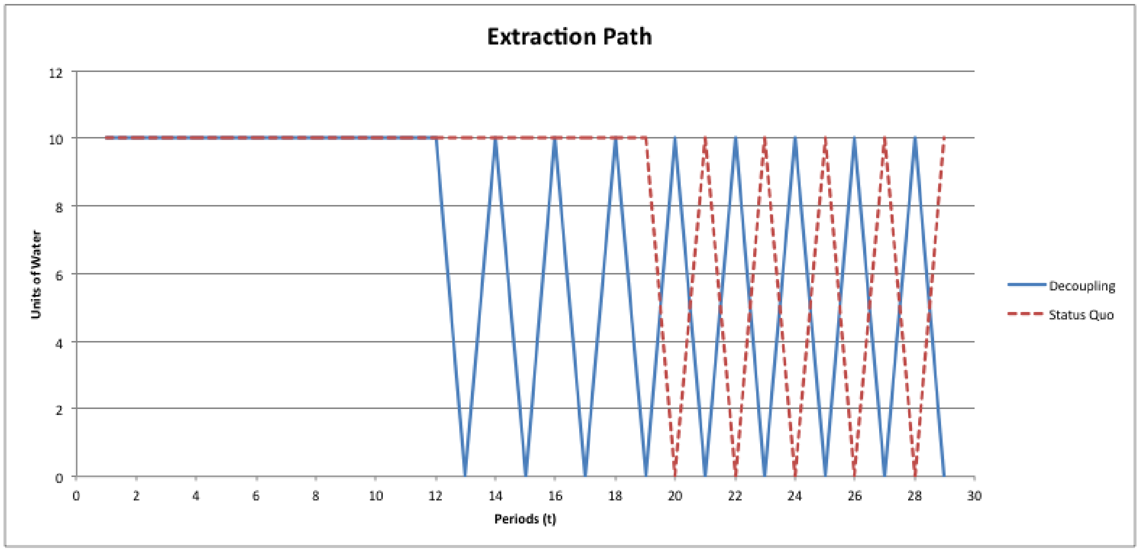


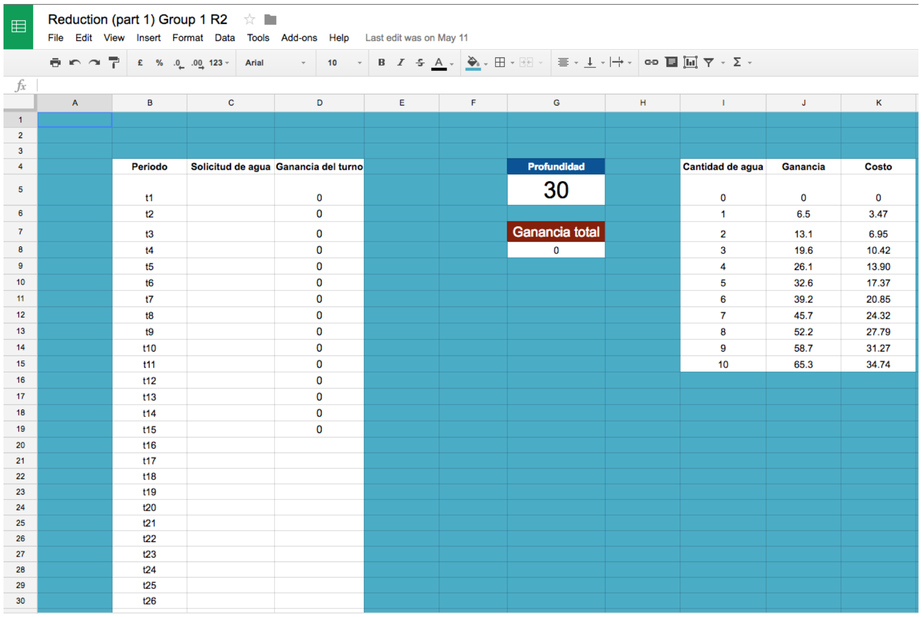
Figure 3. Extraction path.

4 Field Experiments

To test the hypothesis stated in the previous section, we designed an experiment to be implemented in the city of León, Guanajuato with farmers who were recruited with the help of the local water authority and the School of Economics at the National Autonomous University of Mexico. We recruited a total of 84 farmers, who were randomly assigned to groups of 6. The experiment was divided into two parts: all the subjects participated in the Status Quo condition in Part 1, and then proceeded to participate in the policy intervention (Elimination, Reduction, or Decoupling) in Part 2. The subjects in the control group participated in the Status Quo condition in both parts of the experiment. Communication between group members was not allowed.

Each group member was assigned a separate computer. Subjects were given time to read and understand instructions. This phase was followed by a short oral summary of the instructions, after which participants' questions were answered. Sessions lasted no more than two hours, including check-in and payment.

A simple version of a programmed smart sheet using the Google docs platform was presented in this experiment. Subjects were presented with a computer screen that exhibited a space to submit their request for each period. In addition, they were informed of the current depth of the aquifer, the accumulated earnings (measured in tokens), and the potential profit for every possible request at the current depth of the aquifer and the cost associated with it. See Figures 4 and 5.



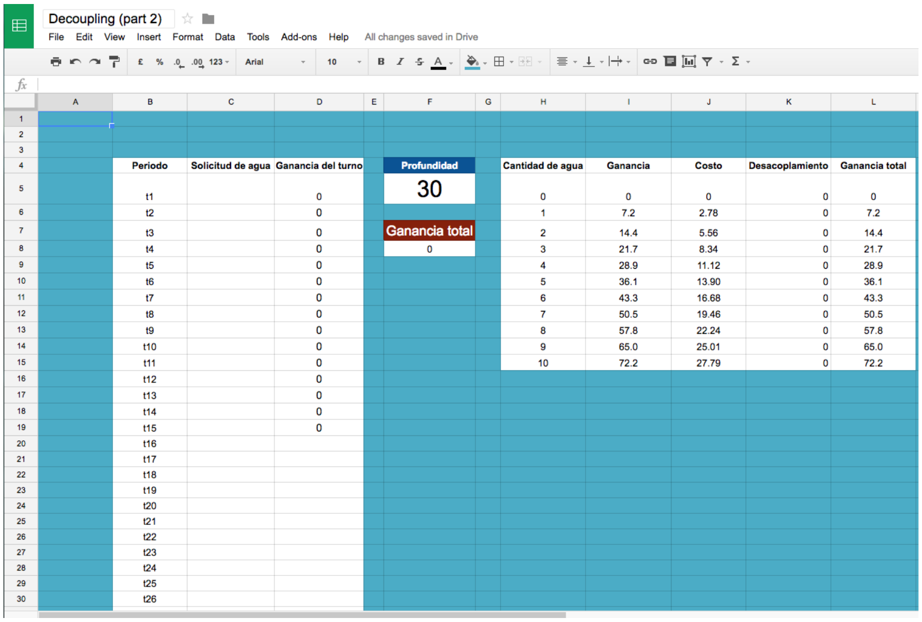
Periodo	Solicitud de agua	Ganancia del turno
t1		0
t2		0
t3		0
t4		0
t5		0
t6		0
t7		0
t8		0
t9		0
t10		0
t11		0
t12		0
t13		0
t14		0
t15		0
t16		
t17		
t18		
t19		
t20		
t21		
t22		
t23		
t24		
t25		
t26		

Profundidad
30

Ganancia total
0

Cantidad de agua	Ganancia	Costo
0	0	0
1	6.5	3.47
2	13.1	6.95
3	19.6	10.42
4	26.1	13.90
5	32.6	17.37
6	39.2	20.85
7	45.7	24.32
8	52.2	27.79
9	58.7	31.27
10	65.3	34.74

Figure 4. Participant's screen.



Periodo	Solicitud de agua	Ganancia del turno
t1		0
t2		0
t3		0
t4		0
t5		0
t6		0
t7		0
t8		0
t9		0
t10		0
t11		0
t12		0
t13		0
t14		0
t15		0
t16		
t17		
t18		
t19		
t20		
t21		
t22		
t23		
t24		
t25		
t26		

Profundidad
30

Ganancia total
0

Cantidad de agua	Ganancia	Costo	Desacoplamiento	Ganancia total
0	0	0	0	0
1	7.2	2.78	0	7.2
2	14.4	5.56	0	14.4
3	21.7	8.34	0	21.7
4	28.9	11.12	0	28.9
5	36.1	13.90	0	36.1
6	43.3	16.68	0	43.3
7	50.5	19.46	0	50.5
8	57.8	22.24	0	57.8
9	65.0	25.01	0	65.0
10	72.2	27.79	0	72.2

Figure 5. Participant's screen for decoupling condition.

The procedures are summarized below.

Part 1

Condition 1: Status quo (no change of subsidy).

All subjects participated in this condition. They were instructed to extract groundwater (from zero to 10 meters) to be pumped from the aquifer. The height of the water table was set at 30 meters for the first period. After period 1, each subject could inspect the current height of the water table for each period in the main screen and the potential profit for each of the possible water requests. After the group members submitted their requests, the water table was updated and they were asked to submit new requests independently. Because the extraction game was played under an infinite time horizon, each round was terminated randomly with a conditional probability of 15% contingent on reaching this round. At the end of the session, subjects were paid anonymously, contingent on their performances, and dismissed from the laboratory.

Part 2

Condition 2: Elimination of the subsidy.

Subjects were asked to perform the same task as in Part 1, with the same conditional probability of termination. In this condition, the value of γ was set equal to one, thereby implying the complete elimination of the subsidy.

Condition 3: Reduction of the subsidy.

In this condition, the value of γ was set equal to 0.5, meaning that the new subsidy was only 50% of the pumping costs. Subjects performed the same task as in Part 1, with the same conditional probability of termination.

Condition 4: Decoupling (elimination of the subsidy and transfer of payment).

In this condition, subjects participated in Part 1, then were informed that the average subsidy received during the first 15 periods would be their decoupling factor. Each subject was informed individually, and all were informed collectively that the subsidy in Part 2 would be removed ($\gamma = 1$). Then, they were asked to perform the same task as in Part 1 with the same conditional probability of termination.

Condition 5: Control.

In Condition 5, the subjects performed the same task as in Part 1. After the random termination of that part of the experiment, they proceeded to participate in Part 2 with the same level of subsidy ($\gamma = 0.2$), until it was randomly terminated.

Results

The results of the field experiment are summarized in this section. We do not compare the behavior in part 1 across all conditions; rather, the analysis is conducted by comparing the behavior of the groups in Part 1 of each condition with the behavior of groups in part 1 of the control condition.

Elimination

For the elimination condition, 18 farmers were assigned randomly to three groups of six members each. Subjects were given time to read the instructions at their own pace, followed by a brief oral summary of the instructions and a short question-and-answer period. This procedure was followed in all conditions.

In this section, we compare the behavior of groups in the status quo condition (Part 1) and the elimination condition (Part 2). Figure 6 indicates that the mean total request per group in the elimination condition is consistently lower than the one in the status quo condition; subjects understood quickly that the costs increased after the subsidy was eliminated and consequently played more conservatively than they did in the first period.

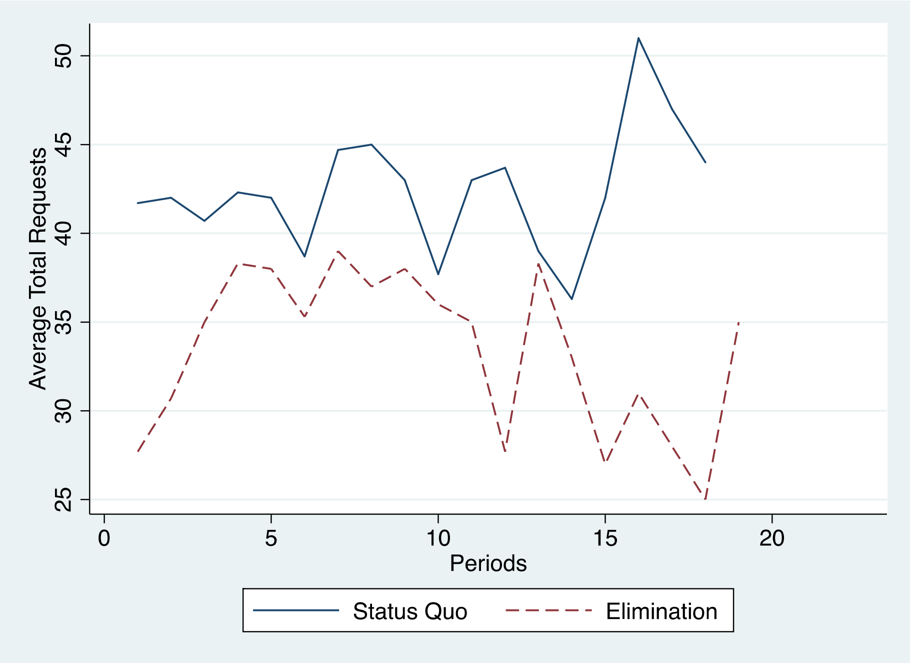


Figure 1. Mean individual requests per group.

A *t*-test was performed to test the hypothesis that the mean request in the status quo and elimination conditions would be the same. The test indicated that the difference between the mean is statistically significant ($t = 5.97$, $p < 0.001$). Note that this is not a measure of the magnitude of the treatment effect, which will be discussed in later sections.

The effects of the extraction decisions shown in Figure 6 are reflected in the height of the water table. Figure 7 demonstrates that the value of the height of the water table under the status quo gradually increases from 30 meters to about 100 meters, whereas the height of the water table in the elimination condition fluctuates between 30 and 50 meters.

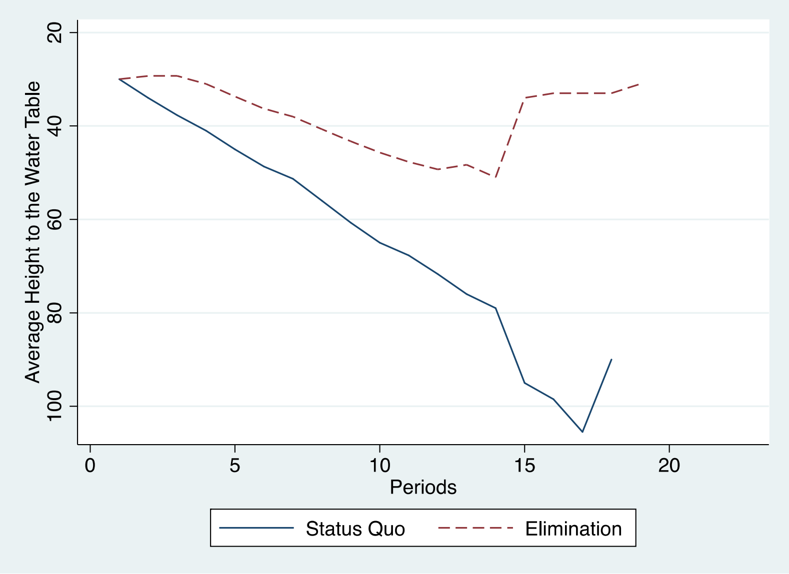


Figure 2. Mean height of the water table (in meters).

Reduction

In the reduction condition, the subjects were instructed to perform the same task as they did previously, except in this condition, they were faced with a reduction in the subsidy level from 80% to 50%. Figure 8 demonstrates that the effect of the reduction to 50% of the subsidy is considerably weaker. This sensitivity to the change in subsidy level is confirmed by a *t*-test ($t = -0.81$, $p > 0.2$), which shows that the difference in requests between the first and second parts of the experiment is not statistically significant.

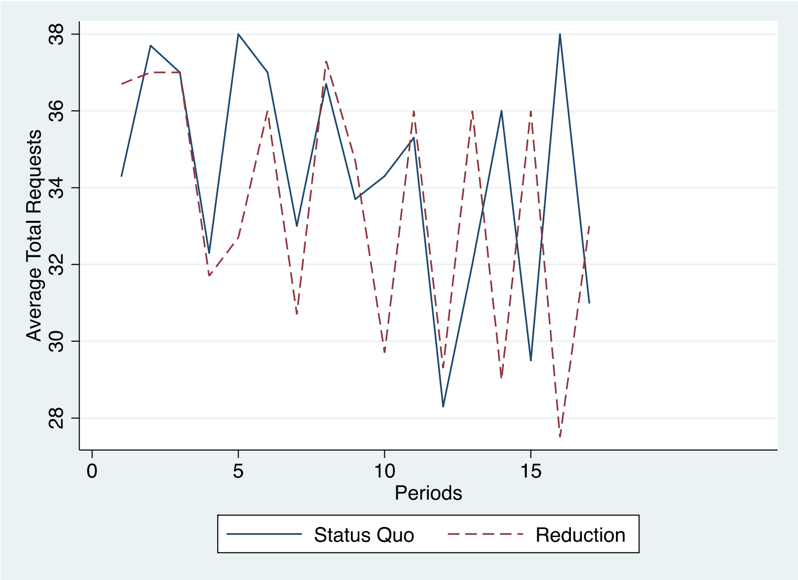


Figure 3. Mean individual requests (reduction condition).

Figure 9 indicates that the lower requests had only a minor effect on the height of the water table. Under reduction, the height of the water table is lower.

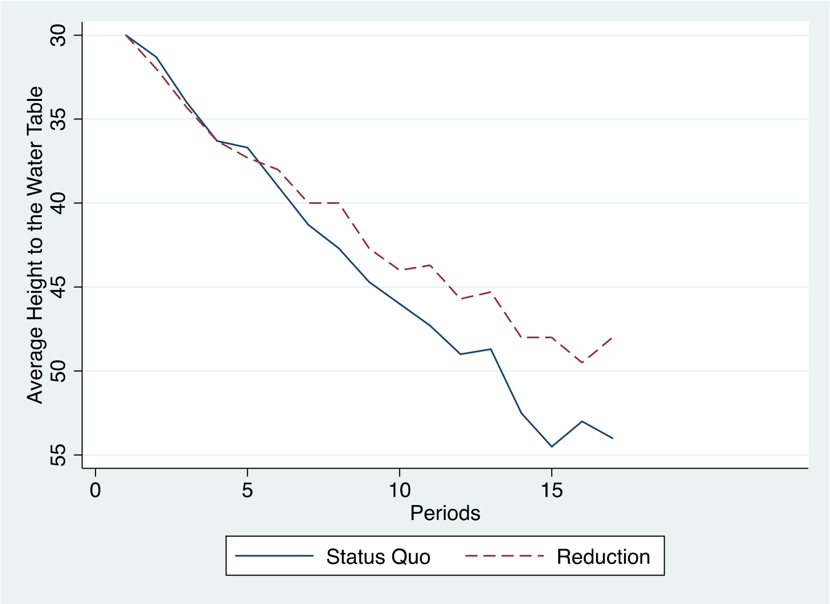


Figure 4. Mean height of the water table (reduction condition).

Decoupling

The decoupling condition was performed in the same manner as in the previous two conditions; however, after completing Part 1, the subjects were informed of the size of the individual decoupling factor and then proceeded to play Part 2, where the subsidy was completely eliminated and replaced by cash transferred.

Figure 10 depicts the mean total request by the group. It shows that the requests under the decoupling condition are consistently lower than under the status quo condition. The difference between the two mean requests is statistically significant (t = -2.42, $p <$ 0.001). The extraction values under this condition meet the theoretical predictions presented in the previous sections more closely than those under any other condition.

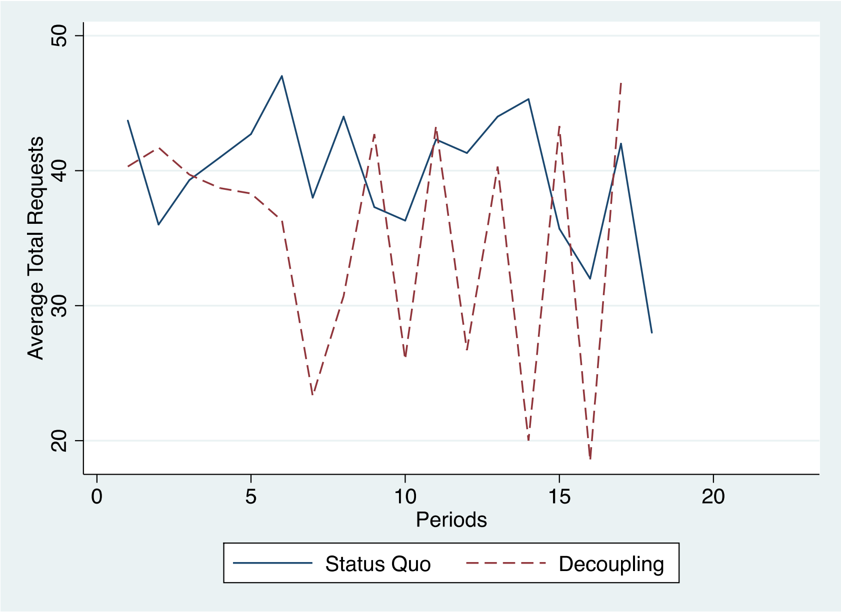


Figure 5. Mean individual requests (decoupling condition).

This periodic request changes in Figure 10 are reflected in the height of the water in Figure 11. This figure shows that the trend stabilizes after period 5 at 60 meters, whereas the height of the water table in the status quo condition follows the trend, as in the previous two treatments (compare Figures 7, 9, and 11).

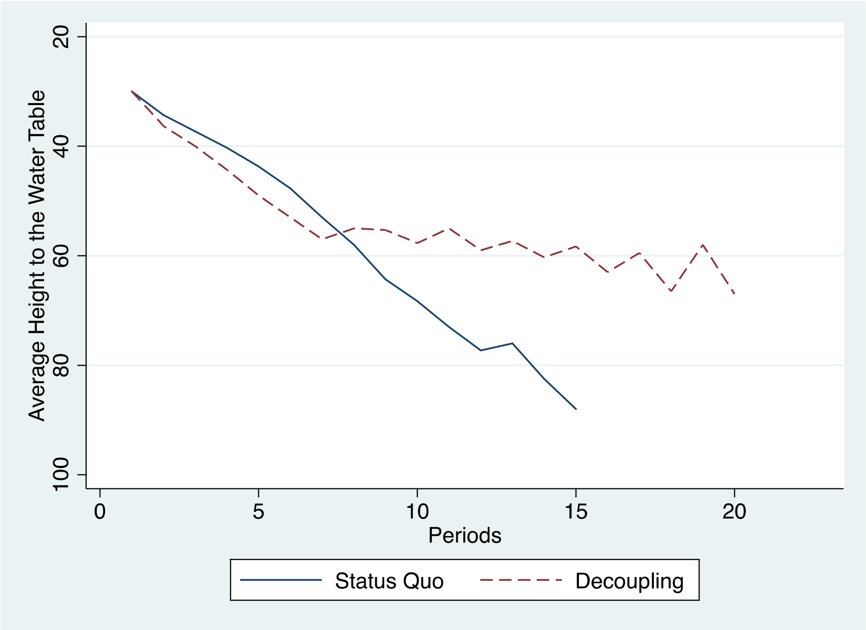


Figure 6. Mean height to the water.

Quantifying Policy Intervention Effectiveness

To analyze the effects of the policy interventions quantitatively, we employ the difference in differences method, following the analysis conducted in Tellez Foster et al. (2016b). This technique often is used in the literature to analyze the effect of treatment across populations. It compares the behavior of individuals before and after receiving treatment to a counterfactual population. The model estimated is represented by:

$$\Delta u = \beta_1\ Pretreatment + \ \beta_2\ Post - treatment + \beta_3\ Interaction\ term\ (pre * post),$$

where Δu is the change in the requests for groundwater after the treatment is applied, β_1 is the estimator for the status quo condition, β_2 is the treatment estimator, and β_3 is the relevant estimator in obtaining the final effect of the treatment.

The treatment effects for the three conditions is presented in Tables 1, 2, and 3 below:

Table 1

Difference in Differences Estimation (Elimination)

Number of observations in the Diff-in-Diff: 1386

	Baseline	Follow-up	
Control:	402	408	810
Treated	294	282	576
	690	696	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	6.015			
Treatment (T)	7.017			
Diff (T-C)	1.002	0.208	4.81	0.000***
Follow-up				
Control (C)	6.301			
Treatment (T)	5.720			
Diff (T-C)	-0.582	0.210	-2.77	0.006***
Treatment effect	-1.584	0.296	-5.35	0.000***

Inference: *** $p<0.01$; ** $p<0.05$; * $p<0.1$

We observe that the reduction per period per individual is 1.5 units of water. This confirms our hypothesis that the sign of the effect is negative. The effect we observe in elimination is the greatest among all the treatments, which also coincides with the theoretical predictions made by Tellez Foster et al. (2016b).

Table 2

Difference in Differences Estimation (Reduction)

Number of observations in the Diff-in-Diff: 1386

	Baseline	Follow-up	
Control:	402	408	810
Treated	276	270	546
	678	678	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	6.015			
Treatment (T)	6.395			
Diff (T-C)	0.380	0.206	1.85	0.065**
Follow-up				
Control (C)	6.301			
Treatment (T)	5.722			
Diff (T-C)	-0.579	0.206	-2.81	0.005***
Treatment effect	-0.959	0.291	-3.29	0.001***

Inference: *** $p<0.01$; ** $p<0.05$; * $p<0.1$

For reduction we expected a smaller effect, following the theoretical predictions presented above. Reducing the subsidy from 80% to 50% resulted in the requests being reduced by an average of less than one unit only. However, the cumulative effect demonstrates an increase in the height to the water table, as shown in the previous section.

Table 3

Difference in Differences Estimation (Decoupling)

Number of observations in the Diff-in-Diff: 1386

	Baseline	Follow-up	
Control:	408	402	810
Treated	252	318	570
	660	720	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	6.301			
Treatment (T)	7.369			
Diff (T-C)	1.068	0.208	5.12	0.000***
Follow-up				
Control (C)	6.015			
Treatment (T)	5.874			
Diff (T-C)	-0.141	0.258	-0.54	0.586
Treatment effect	-1.208	0.331	-3.65	0.000***

Inference: *** $p<0.01$; ** $p<0.05$; * $p<0.1$

The treatment effect in the decoupling condition is close to the one calculated for the elimination treatment. It also shows the expected negative sign and it is close to the theoretical prediction that stated the same effect for elimination and decoupling conditions.

Robustness of the Results

Comparing the results of the laboratory experiments presented in Tellez Foster et al. (2016b) with the results of the field experiments presented in this paper leads to a more comprehensive understanding of how policy interventions affect water requests and, consequently, in the height of the water. Table 4 presents the treatment effect of the three conditions, calculated using the difference in differences method.

Table 4

Comparison of Treatment Effect: Laboratory vs Field Experiments

Condition	Laboratory	Field
Elimination	-0.789 (0.342)***	-1.584 (0.296)***
Reduction	-1.534 (0.310)***	-0.959 (0.291)***
Decoupling	-2.015 (0.272)***	-1-208 (0.331)***

(S. Err) ***p<0.01; **p<0.05; *p<0.1

Table 4 demonstrates that in both sets of experiments (laboratory and field) the sign of the treatment is negative, as predicted in the theoretical model. However, differences in the magnitude of the effect must be analyzed carefully. The strongest effect observed among the laboratory experiments was for the decoupling condition, followed by the reduction and the elimination conditions. Among the experiments conducted in the field, the elimination of the subsidy had the greatest effect, and the reduction had the smallest. Analyzing how the magnitude of the treatment effect varies across different populations, the plausible explanation for the difference in behavior could be explained by the experience that farmers have had with the problema; therefore, their behavior was closer to what was predicted by the theoretical model.

Although the purpose of this paper is not to investigate the differences between laboratory and field experiments, it will present analysis comparing the two sets of experiments.

Comparing Results with Previous Studies

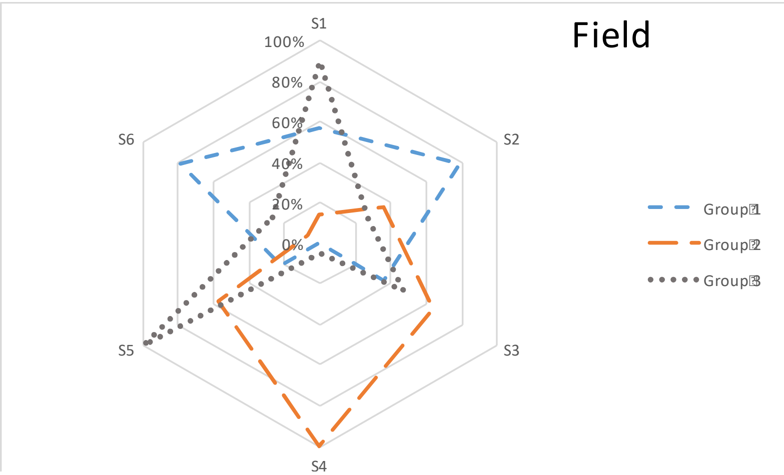
This section compares the results of the experiments conducted in the field with those obtained in laboratory experiments in Tellez et al. (2016(b)). The treatment effect resulted in the expected sign for all conditions and in both student and farmer populations. However, we observe that farmers' behavior follows the predictions of the theoretical model closely, which could be explained by the prior knowledge that farmers bring to the experiment.

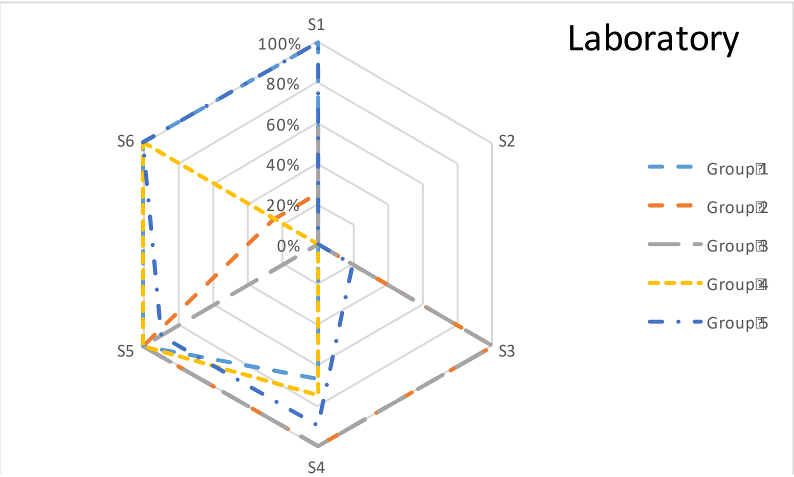
Analyzing Free-Riding Behavior

One of the measures in which students and farmers' behavior differ is in free riding the conservation efforts of others. Figure 12 demonstrates the number of periods that a participant requested above the average request of the group as a percentage of the total number of periods. The graphs indicate that students in the laboratory were more prone to request above the average, free riding the efforts of other participants to preserve the resource.

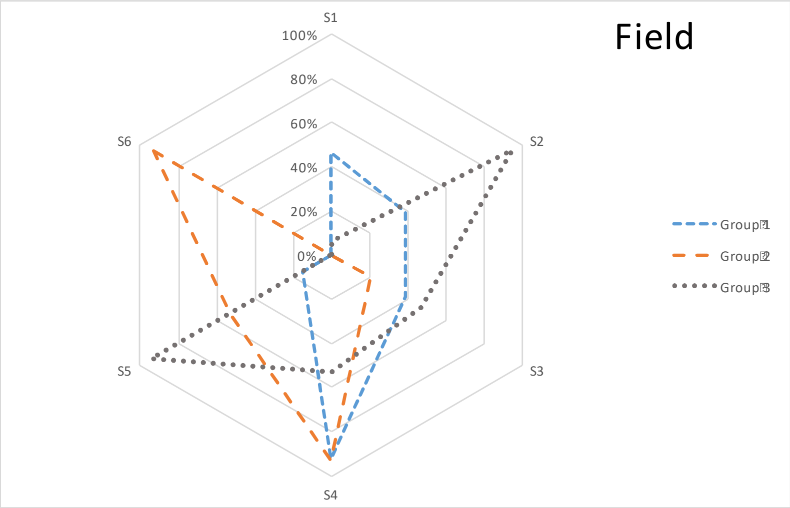
Free-riding behavior was not affected by the treatment, and the graphs below show that students consistently made requests over the average, undermining the efforts of other players to preserve water. On the other hand, farmers were less likely to free ride the efforts of others in conserving water. The figure demonstrates that the number of requests above the group average for farmers is significantly lower than those of students. A *t*-test was conducted to assess the statistical significance of the mean difference between field and laboratory participants, showing that in a two-tailed test, the mean difference is not zero with a *p* value of 0.0042. Meanwhile, in a single-tailed test, the *p* value for a difference less than 0 was 0.0021. These results confirm that the free-rider behavior for the field experiments statistically were significantly lower than the behavior shown by participants in the laboratory.

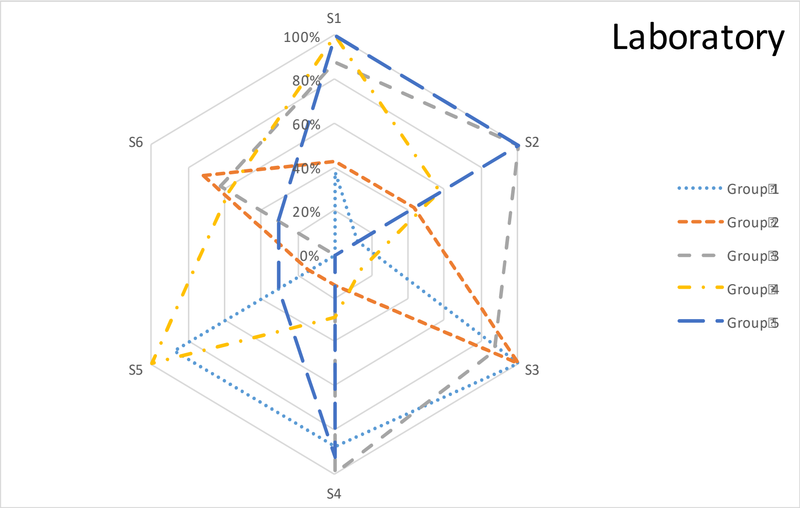
Elimination





Reduction





Decoupling

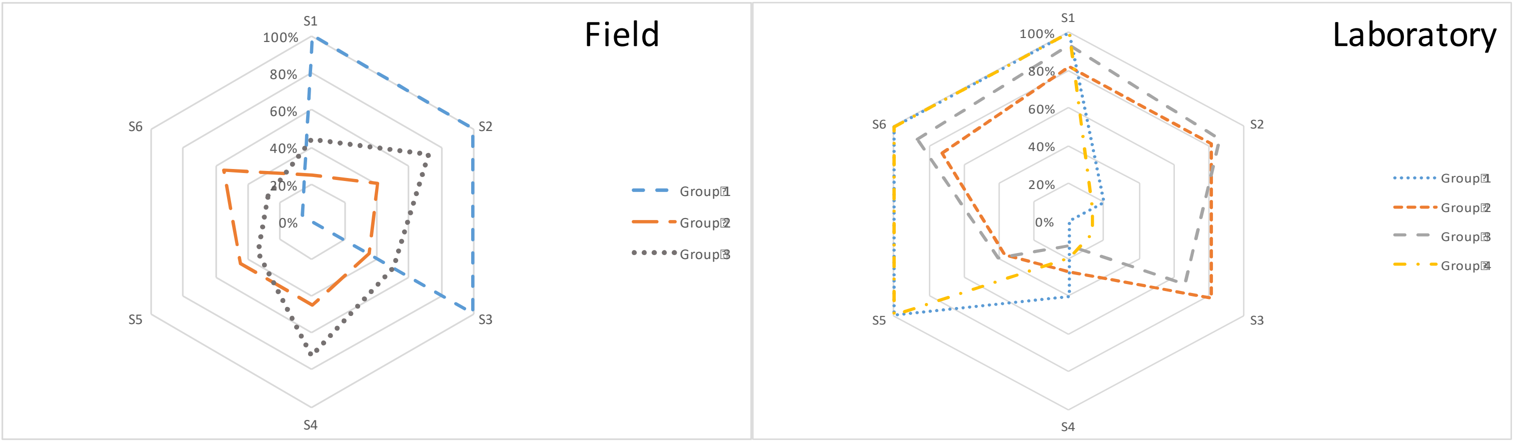


Figure 12. Percentage of periods of individual requests exceeding the group average.

In an analysis of how many average free riders per group we find per condition, we define a free rider as a participant that requests above the average group request for 50% or more of the periods. Table 5 demonstrates that students partake in free-riding behavior consistently more than farmers do. This reinforces that the experience farmers possess is reflected in their decisions, even in abstract settings such as that of this experiment.[3]

Table 5

Average Number of Participants Free Riding Per Condition

Condition	Laboratory	Field
Elimination	3.6	2.7
Reduction	3.4	2.3
Decoupling	3.5	2

Conclusions and Policy Implications

This paper sheds light on the behavioral changes of groundwater users under different policy interventions in the context of perverse subsidies to electricity. Its conclusions on the implications of policy modifications are presented in this section.

---

[3] We are unable to test this hypothesis because of restrictions of the HHRRB on collecting personal data of participants.

Predicted Behavior vs. Observed Behavior

We found several trends in the number of requests and height of water table variables by comparing the behavior of subjects under the status quo condition and the policy interventions. All three interventions resulted in a reduction in the requests per period. Although hypotheses predicted that elimination and decoupling would accomplish the same result, we found that elimination had a greater effect, followed closely by decoupling with a 0.3 units of difference. Reduction of the subsidy resulted in the smallest effect, with less than one unit on average per period.

In all cases, subjects demonstrated an understanding of the consequences of changing the subsidy structure and acted consequently, and users' strategies were more aggressive in the first part of the experiment before they adopted more conservative strategies after the treatment is applied.

Policy Implications

Changes in the institutional arrangements of water management are slow and costly; they often face resistance from decision-makers and users. The results derived from these experiments, both in the laboratory and in the field, provide an efficient and cost-effective method of analyzing the effects of policy interventions before they are applied.

We observe some outstanding differences in the magnitude of the treatment effect between laboratory and field experiments for two particular treatments: elimination and reduction. In the case of laboratory results, we observe a larger effect for the latter, with an average reduction of more than one unit per period, as compared with a reduction of less than one unit for the elimination treatment. For the field results, the magnitude of the effect seems to be reversed, with elimination showing a reduction of about 1.5 units per period and for the reduction treatment a decrease of less than one unit per period. This adds to the discussion presented above about the differences in the behavior of students and farmers and opens the discussion to considering the unobserved factors that influence this behavior. These questions are subject to further research.

Our research has demonstrated that changing the subsidy structure for groundwater extraction has significant effects on the extraction levels and consequent height of the water table. The three policy interventions investigated in the present study prove to have the desired effect; namely, a reduction in the requests for groundwater. As expected, elimination of the subsidy produced the strongest effect. However, as discussed in Muñoz et al. (2006) and Tellez Foster et al. (2016b), eliminating the subsidy is not politically feasible. Reducing the subsidy produces a limited effect (less than one unit per period on average), and its implementation most likely would face the same political difficulties. Decoupling the subsidy has an effect close to the one observed in the Elimination condition without the averse political difficulties. Therefore, we propose decoupling as an alternative policy intervention in overcoming the political obstruction.

References

Asad, M., & Dinar, A. (2006). The role of water policy in Mexico: Sustainability, equity, and economic growth considerations (Working Paper No. 27). *Latin America and Caribbean Region Sustainable Development* (pp. 22). World Bank, Washington, DC.

Bailey, M., Sumaila, U. R., & Lindroos, M. (2010). Application of game theory to fisheries over three decades. *Fisheries Research*, *102*(1), 1-8.

Barrett, S., & Dannenberg, A. (2012). Climate negotiations under scientific uncertainty. *Proceedings of the National Academy of Sciences*, *109*(43), 17372-17376.

Botelho, A., Dinar, A., Pinto, L. M., & Rapoport, A. (2014). Time and uncertainty in resource dilemmas: Equilibrium solutions and experimental results. *Experimental Economics, 52,* 1-24.

Botelho, A., Fernandes, E., & Pinto, L. (2012). An experimental analysis of grandfathering versus dynamic auctioning in the EU ETS. *Experiments on Energy, the Environment and Sustainability (Research on Environmental Economics), 4,* 37-76.

Brozovic, N., Sunding, D. L., & Zilberman, D., (2006). On the spatial nature of the groundwater pumping externality. Paper presented at the annual meeting of the American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association), Long Beach, California.

Budescu, D. V., Rapoport, A., & Suleiman, R. (1990). Resource dilemmas with environmental uncertainty and asymmetric players. *European Journal of Social Psychology, 20,* 475–487.

Burness, H. S., & Brill, T. C. (2001). The role for policy in common pool groundwater use**.** *Resource and Energy Economics, 23,* 19-40.

Cardenas, J. (2011). Social norms and behavior in the local commons as seen through the lens of field experiments. *Environmental and Resource Economics, 48,* 451-485.

Cardenas, J. and Ostrom, E. (2004). What do people bring into the game? **(**CAPRi Working Paper No. 32). International Food Policy Research Institute.

Castillo, D., & Saysel, A. K. (2005). Simulation of common pool resource field experiments: A behavioral model of collective action**.** *Ecological economics, 55,* 420-436.

CONAGUA, (2010). Estadísticas del agua**.** Comisión Nacional del Agua.Mexico.

Dinar, A. (Ed.) (2000). *The political economy of water pricing reforms.* Oxford: Oxford University Press.

Dinar, A., Guerrero Garcia Rojas, H. R., Yunez-Naude, A., & Medellin-Azuara, J. (2008). Politicas en el sector agua, instrumnmentos para la evaluacion de dus consecuencias economicas y ambientales. *Lecturas, 100,* 11-29.

Dubash, N. K. (2007). The electricity-groundwater conundrum: Case for a political solution to a political problem. *Economic and Political Weekly, 42,* 45-55.

Esteban, E. & Albiac, J. (2011). Groundwater and ecosystems damages: Questioning the Gisser-Sánchez effect. *Ecological Economics, 70,* 2062-2069.

Esteban, E.,& Albiac, J. (2012). The problem of sustainable groundwater management: The case of La Mancha aquifers. *Hydrogeology Journal, 20*, 851-863.

Feinerman, E and, Knapp K, (1983). Benefits from groundwater management: Magnitude, sensitivity, and distribution**.** *American Journal of Agricultural Economics, 65,* 703-710.

Fischer, M. E., Irlenbusch, B., & Sadrieh, A. (2004). An intergenerational common pool resource experiment. *Journal of Environmental Economics and Management, 48,* 811-836.

Fisher, A., Wheeler, W. J., & Zwick, R. (1993). Experimental methods in agricultural and resource economics: How useful are they? *Agricultural and Resource Economics Review, 22*.

Gardner, R., & Walker, J. (1994). *Rules, games, and common-pool resources*. Ann Arbor: University of Michigan Press.

Gisser M., & Sanchez D. (1980). Competition versus optimal control in groundwater pumping. *Water Resources Research, 31*, 638–642 .

Hardin, G. (1968). The tragedy of the commons. *Science, 162* (3859), 1243-1248.

Hellegers, P., Zilberman, D., & van Ierland, E. (2001). Dynamics of agricultural groundwater extraction. *Ecological Economics, 37,* 303-311.

Jain, V. (2006). Political economy of electricity subsidy: Evidence from Punjab. *Economic and Political Weekly, 41*(38), 4072-4080.

Kim, C., Moore, M. R., Hanchar, J. J., & Nieswiadomy, M. (1989). A dynamic model of adaptation to resource depletion: Theory and an application to groundwater mining. *Journal of Environmental Economics and Management, 17*, 66-82.

Koundouri, P. (2004). Current issues in the economics of groundwater resource management. *Journal of Economic Surveys, 18*, 703-740.

Miranda, M., & Fackler, P. (2007). Computational Methods in Economics. MATLAB Toolbox. Retrieved from http://www4. ncsu. edu/unity/users/p/pfackler/www/ECG790C.

Miranda, M. J., & Fackler, P. L. (1997). CompEcon Toolbox for MATLAB.

Miranda, M. J., & Fackler, P. L. (2002). *Applied computational economics and finance.* Cambridge: MIT Press.

Monari, L. (2002). Power Subsidies. A reality check on subsidizing power for irrigation in India. *Public Policy for the Private Sector.* World Bank. (Note No. 244).

Mukherji, A., & Shah, T. (2005). Groundwater socio-ecology and governance: A review of institutions and policies in selected countries. *Hydrogeology Journal, 13*, 328-345.

Muñoz, C., Avila, S., Jaramillo, L. A., & Martinez, A. (2006). Agriculture demand for groundwater in Mexico: Impact of water enforcement and electricity user-fee on groundwater level and quality. Working Paper INE-DGIPEA/0306. Instituto Nacional de Ecología.

Murayama, C. (2006). El agua en números. Periódico La Crónica de hoy.

Murphy, J. J., Dinar, A., Howitt, R. E., Rassenti, S. J., & Smith, V. L. (2000). The design of "smart" water market institutions using laboratory experiments. *Environmental and Resource Economics, 17,* 375-394.

Myers, N. (1999). Perverse subsidies. *Royal Society for the Encouragement of Arts [RSA] Journal,* 147, 84-91.

Ostrom, E. (1990). Governing the commons: The evolution of institutions for collective action. Cambridge: Cambridge University Press.

Parker, J. A. (2008). Euler equations. The New Palgrave Dictionary of Economics. In S. N. Durlauf & L. E. Blume, *The new Palgrave dictionary of economics online*. Palgrave Macmillan.

Pearce, D. (2003). Environmentally harmful subsidies: Barriers to sustainable development. Environmentally Harmful Subsidies: Policy Issues and Challenges. *OECD, Paris*, 9-32.

Salcedo, R., Shortle, J. S., & Gutiérrez, M. A. (2013). Cooperation makes it happen? Groundwater management in Aguascalientes: An experimental approach. Unpublished. Retrieved from http://www.feem-web.it/ess/ess12/files/papers/salcedo.pdf.

Shah, T., Scott, C., & Buechler, S. (2004). Water sector reforms in Mexico: Lessons for India's new water policy. *Economic and Political Weekly*, *39*(4), 361-370.

Shah, T., Singh, O., & Mukherji, A. (2006). Some aspects of South Asia's groundwater irrigation economy: Analyses from a survey in India, Pakistan, Nepal Terai and Bangladesh. *Hydrogeology Journal, 14,* 286-309.

Shiklomanov, I. A. (1993). World fresh water resources. In P. H. Gleick (Ed.) *Water in crisis: A guide to the world's fresh water resources*. Oxford: Oxford University Press, Inc.

Strand, J. (2012). Allocative inefficiencies resulting from subsidies to agricultural electricity use. An illustrative model (Working Paper No. 5955). The World Bank.

Suter, J. F., Duke, J. M., Messer, K. D., & Michael, H. A. (2012). Behavior in a spatially explicit groundwater resource: Evidence from the lab. *American Journal of Agricultural Economics, 94*: 1094-1112.

Tellez Foster Edgar, Dinar Ariel, R. A. (2016a) . Comparing Alternative Policy Interventions for Modifications of Subsidized Energy: The Case of Groundwater Pumping for Irrigation. *UCR School of Public Policy working paper series No. 2:* *http://spp.ucr.edu/publications/working-papers.html*

Tellez Foster Edgar, Rapoport Amnon, D. A. (2016(b)). Groundwater and electricity consumption under different energy subsidies conditions. Evidence from Laboratory Experiments. UCR School of Public Policy working paper series No. 3. http://spp.ucr.edu/publications/working-papers.html

Velez, M. A., Strandlund, J. K., & Murphy, J. J. (2005). What motivates common pool resources users? Experimental evidence from the field **(**Working Paper No. 4). Department of Economics. University of Massachusetts, Amherst.

Ward, J.R., Tisdell J.G., Straton A., & Capon, T. (2006). An empirical comparison of behavioral responses from field and laboratory trials to institutions to manage water as a common pool resource. Paper presented at the IASCP conference, Bali, Indonesia.