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Alternative policies for subsidizing groundwater extraction: A field study in Mexico

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Abstract
We design a field experiment to study the behavior of farmers under alternative electricity subsidies for extracting groundwater in Mexico. The paper proposes a model for the extraction of groundwater over multiple periods, and then examines the effectiveness of three policy interventions: elimination, reduction, and decoupling. Results from a field experiment conducted in the city of León, Guanajuato, México, show that all the three proposed 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 groundwater extraction. Decoupling proves to be a viable policy, as it produces an effect similar to elimination while reducing possibly undesirable political implications. We then compare these results with a laboratory experiment conducted with US undergraduate students, and report significant differences between the laboratory and field studies.

JEL Classification: Q5; Q2; Q25; C9; C92

Keywords
groundwater extraction — electricity subsidies — field experiments

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Introduction

As defined by Ostrom, Gardner, and Walker (1994), common pool resource (CPR) dilemmas concern particular classes of goods or events that share two attributes. These attributes are the difficulty of excluding appropriators of the good from benefiting from it, and the substractability of the benefits consumed by one appropriator from those available to other members of her group. Primary examples that have been considered in length in the literature include the management of fishery resources, deforestation, climate change, and the excessive extraction of groundwater. As noted, too, by Ostrom et al., given the wide diversity of CPRs that exist in field settings, "the task of understanding behavior related to this class of goods is both difficult and of considerable policy importance" (1994, p. 7). Most of the practically important problems related to the use, or more appropriately the abuse, of CPRs concern situations where the same set of appropriators use the same resource repeatedly. Consequently, CPR dilemmas are difficult because their size may change over time in large part as a function of previous user appropriation (e.g., bailey et al., 2010; Barrett and Dannenberg, 2012: Koundouri, 2004). Another source of difficulty associated with repetition of the CPR is that appropriators of the good are typically faced with uncertainty about the duration of the dilemma that, due to changes in governmental regulations, environmental catastrophies, and other exogenously determined factors, may be terminated without prior notice. Dynamic models that account for strategic behavior of the CPR appropriators under these sources of uncertainty have been proposed, among others, by Herr, Gardner, and Walker (1997), Mason and Phillips (1997), and Botelho, Dinar, Pinto, and Rapoport (2014).

To what extent are the predictions of these models about decision behavior and outcomes of finitely repeated CPR dilemmas supported by empirical evidence? One approach to answer this question is to conduct carefully designed laboratory experiments that closely match the conditions specified in the theoretical models. In parametrizing the CPR dilemmas in the laboratory, one may control the population of the appropriators, the group size, the decisions that they make and the outcomes that they affect, the information that they possess when making their decisions, and their potential payoffs. With some qualifications, the results of these experiments may give rise to policy recommendations.

Our present study follows this approach in a study of groundwater extraction in dynamic settings. It differs from previous studies, some of them reviewed briefly below, in three important ways. First, the intertemporal uncertainty that we embed in the CPR setting concerns the duration of the groundwater game rather than the size of the CPR (which is determined exogenously in our study). Second, rather than focusing exclusively on laboratory experiments, we propose conducting both a laboratory study with college students in the United States and a comparable field study with farmers in Mexico. The third difference is that our study is heavily policy oriented. It intends to examine the behavioral responses of utility-maximizing users, whether these are students volunteering for CPR laboratory experiments or farmers actually involved in pumping groundwater for irrigation, to the proposed modifications of the electricity subsidy mechanism for groundwater extraction.

Subsidies

Electricity subsidies for pumping irrigation water are common in many countries around the world. In Mexico, the focus of the present study, a total volume of 29.5 km3 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, called Tarifa 09, for the electricity used in pumping water for irrigation. The subsidy (pesos/KwH) is provided to farmers as a function of the amount of the electricity they use. The subsidized cost of pumping 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; therefore, farmers have only to pay for the cost of extracting groundwater from the aquifers. The current institutional framework with no price that reflects the scarcity value of the water pumped leads to inefficient exploitation of groundwater resources with dire economic and social consequences.

Appropriator population

The theoretical study of CPR dilemmas has taken the form of proposing alternative game-theoretical models of groundwater extraction and testing their implications by simulations. The CPR dilemma has also been studied experimentally in the controlled environment of the laboratory with voluntary participants who are paid cash contingent on their performance. There is always a concern about drawing conclusions from laboratory experiments and applying them in practice because they restrict the sample to university students, who constitute a highly selected group in terms of age, socio-economic status, educational background, and experience. Therefore, differences between the outcomes of controlled experiments in the laboratory and the outcomes of field studies may occur. This issue is of particular concern to studies, like the one discussed in the present paper, which are inspired by social dilemmas in the field and are heavily policy oriented.

Selected previous studies

There is a substantial literature on the theoretical and experimental studies of groundwater extraction. We make no attempt in our present study to review this literature. Rather, we only mention briefly several field and laboratory experiments that are most relevant to our study, in particular to the difference between laboratory and field experiments. Cárdenas (2011) has addressed the importance of field studies by conducting a series of experiments with a mixed population that mostly consisted of participants in the field and also of college students in the laboratory, who participated in exact replications of the field experiments. His experiment has addressed a common CPR decision problem with a negative externality in consumption. He reports that behavior in both laboratory and field experiments did not differ substantially, and speculates that any differences between the two subject populations that did occur were due to the fact that participants in the field and in the laboratory brought different personal experiences to the groundwater extraction game that might have affected their decisions. Cárdenas's comparison of subject populations in experimental and field studies illustrates the value of testing proposals for policy changes in the field with stakeholders, as this offers sound, replicable, and reliable insight into the potential effects of the proposed policies on cost effectiveness and ease of implementation.

Velez et al. (2005) have explored CPRs with a series of experiments in the field. They reported that their subjects balance self-interest and conformity in selecting their strategy. Salcedo et al. (2013) conducted a series of experiments about how cooperation could help reducing the amount of groundwater pumped in the state of Aguascalientes, Mexico. They report 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. Following the study of Cárdenas, Cardenas and Ostrom (2004) have explored cooperation in the commons with experiments conducted in Colombia. Their general results suggest that differences in behavior may be accounted for by the subjects' differential experience.

Like Cardenas (2011), Ward et al. (2006) have demonstrated the relevance of conducting experiments both in the field and in the laboratory. They claim that the environmental and institutional conditions might lead to different results. They conducted laboratory and field experiments, evaluating different institutional arrangements for water administration, and concluded that different arrangements work better in the laboratory than in the field. If their study is replicated successfully, then researchers must take into account different institutional arrangements, social norms, group reputation, and social connections to better transfer experimental results into policy recommendations. An extensive review of experimental economics work with relevance to our work can be found in Harrison and List (2004).

To summarize, the present 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 the aquifer over multiple periods. Using a field experiment, this paper investigates how farmers change their behavior when they are faced with policy interventions that include 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 that policy interventions have on the groundwater pumped from over-drafted aquifers.

Theoretical model and predictions

We follow the model of Tellez Foster et al. (2016), in which an intertemporal optimization problem is presented with a dynamic equation of motion representing changes in the height to the water table over time. Because a detailed exposition of the model is presented in Tellez Foster et al. (2016), we present below a brief summary of the model followed by presentation of its implications.

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

$$B_{jt} = \delta u_{jt} \frac{\gamma P_E \xi}{(\bar{X} - x_t)AS} - C_0, \tag{1}$$

where δ is the constant marginal product of water extracted by farmer j at period t that is denoted by 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. The parameter AS denotes 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 to equal zero.

The equation of motion of the water table is given by

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

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 aquifer area multiplied by the storativity.

The dynamic optimization problem for the aquifer takes the form

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

$s.t.$

$$x_{t+1} = x_t + \frac{J u_t - R}{AS}$$

$$x_t + \frac{J u_t}{AS} \leq \bar{X},$$

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

This model was simulated multiple times 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 of Salcedo et al. (2013).

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:

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

The first order conditions yield the following Euler equation:

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

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

The Euler equation is used to derive the path of extraction. Systematically increasing the value of the parameter gamma from 0 to 1, the value of the numerator in $\frac{\gamma P_E \xi}{(\bar{X} - x_t)AS}$ increases the discounted benefit of extracting one extra unit in the future (λ), thereby leading to a likely decrease in the extractions for every period that will yield a less deep steady-state value for the height to the water table. This is the major hypothesis that we test below.

Policy interventions

After establishing the theoretical framework of the optimization problem, we analyzed a set of policy modifications to be tested in the field. Using the parameters from Salcedo et al. (2013), we simulated the model for 100 periods, varying the value of γ from 0 to 0.8 in increments of 0.1 to examine 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 a steady increase in the height of the water table when the level of subsidy increases, thereby demonstrating that there is a strong connection between the state variable and the subsidy level.

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; it is represented by:

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

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

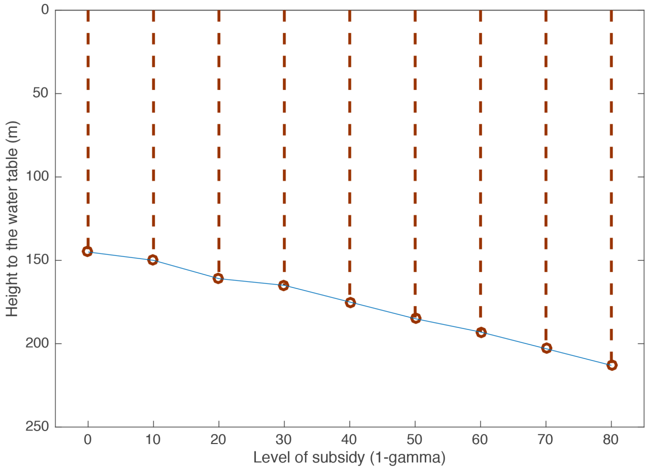

Figure 1. Relationship between the level of subsidy and the height to the water table.

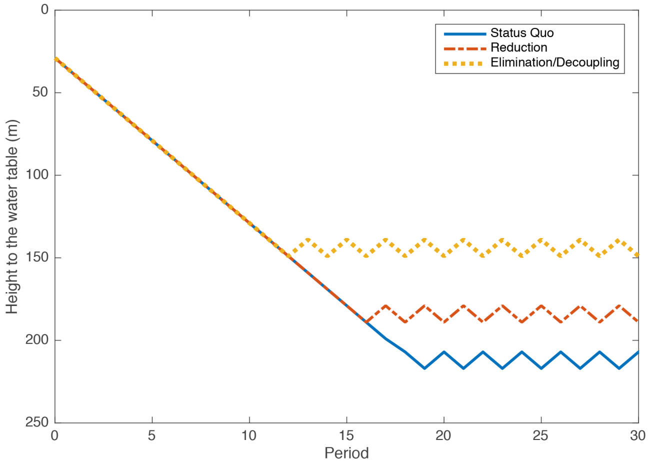

Figure 2. Steady-state of the height to the water table under different policy interventions.

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

In comparison with Equation 3, the respective Bellman equation has the form

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

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

The hypothesis tested in the field experiment states 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 the 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 to the water table, which suggests it to be a viable policy intervention.

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 units, as shown in Figure 3.

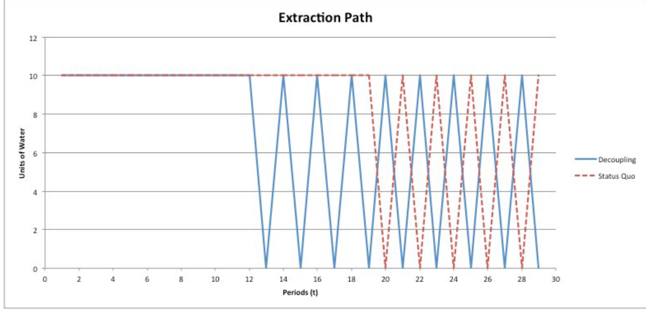

Figure 3. The extraction path.

Field experiment

To test the hypotheses stated in the previous section, we had designed an experiment that was subsequently conducted 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. We refer to this experiment as a laboratory experiment with participants from the field, or briefly as a *field experiment*.

The field experiment in Mexico was originally designed to be as similar as possible to a previous lab experiment in Riverside, California (Tellez et al., 2017). However, several differences between these two studies are inevitable: (1) The laboratory study in Riverside included US undergraduate students, who volunteered to participate in an experiment for payoff contingent on their performance. The present study in Mexico included farmers, who were recruited with the assistance of the National Autonomous University of Mexico. (2) The laboratory study included both males and females in roughly equal shares, whereas the field experiment included only males. (3) Relatedly, the US students were mostly igno-

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[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 detailed explanation of the choice of length of the lag, please refer to Tellez Foster et al. (2016).

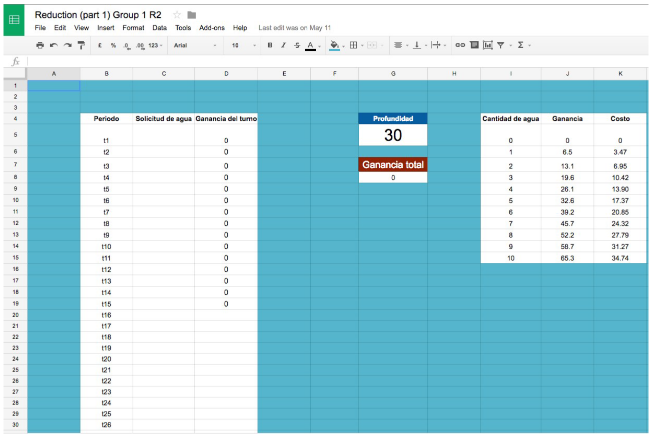
rant about the impact of electricity subsidies on groundwater extraction, whereas these issues have been critical and highly familiar to the farmers in Mexico. (4) The instructions for the lab experiment were presented in English whereas the ones in Mexico were presented in Spanish. (5) In addition to the difference in previous experience with groundwater extraction between the two subject populations, there was also a difference in mean age with higher age of the participants in the field experiment in Mexico.

The field experiment was divided into two parts: all the subjects participated in the Status Quo condition in Part 1, and then proceeded to participate in one of 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. The Subject Instructions (in English) for both Part 1 and Part 2 of the decoupling condition are relegated to an on-line appendix.

Each group member was assigned a separate computer. Subjects were given sufficient time to read and understand the instructions. This phase was followed by a short oral summary of the instructions, after which the participants' questions were answered. Sessions lasted no longer 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 shown 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 (labels in Spanish).

The procedures are summarized below.



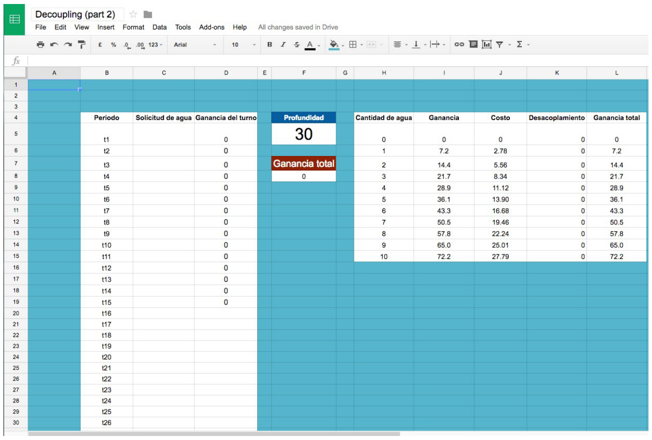
Periodo	Solicitud de agua	Ganancia del turno
t1		0
t2		0
t3		0
t4		0
t5		0
t6		0
t7		0
t8		0
t9		0
t10		0
t11		0
t12		0
t13		0
t14		0
t15		0
t16		
t17		
t18		
t19		
t20		
t21		
t22		
t23		
t24		
t25		
t26		

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. The participant's screen for the reduction condition.



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. The participant's screen for the decoupling condition.

PART 1

Condition 1: Status quo (no change of subsidy)

All the subjects participated in this condition. They were instructed to extract groundwater (from zero to 10 meters) to be pumped from the aquifer. The height to the water table at period 1 was set at 30 meters. After period 1, each subject could inspect the main screen for the current height to the water table for each period, and the potential profit for each of the possible water requests. After the six group members submitted their requests for groundwater independently and anonymously, the water table was updated and the subjects were asked to submit new requests. Because the groundwater extraction game was played under an infinite-time horizon, each round was terminated randomly with a (conditional) probability of 0.15, which is contingent on the group reaching this round. At the end of each period, the extraction game continued with the complementary probability of 0.85 for at least one additional period. At the end of the session, subjects were paid anonymously, contingent on their performance, 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 termination probability 0.15. 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, and then they were informed that the average subsidy of their group 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 ($\gamma = 1$). Subsequently, 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 the same groups in Part 2 of the control condition.

Elimination

For the elimination condition, 18 farmers were assigned randomly to three groups of six members each. Subjects read the instructions at their own pace. After reading the instructions, the session proceeded by the presentation of 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 the 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 were eliminated and consequently played more conservatively than in the status quo condition.

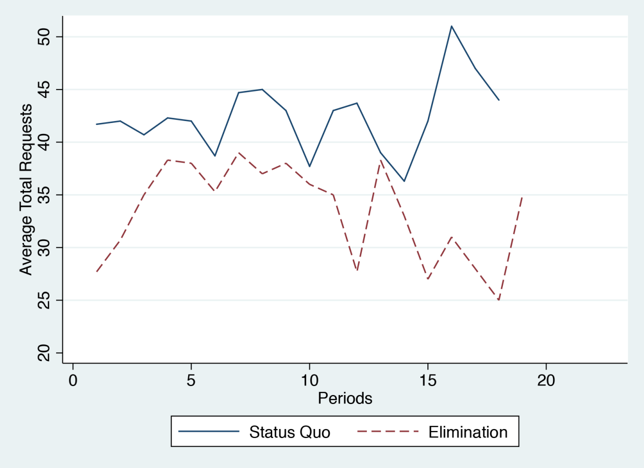


Figure 6. Mean individual requests (Elimination condition and Status Quo) by period.

A t-test was performed to test the hypothesis that the mean requests in the status quo and elimination conditions are the same. Using the individual request for groundwater as the unit of analysis, the test indicated that the difference between the two means 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, which are exhibited in Figure 6, are reflected in the height to the water table. Figure 7 demonstrates that the value of the height to the water table under the status quo gradually increases by a factor of three from 30 meters to about 100 meters, whereas the height to the water table in the elimination condition fluctuates between 30 and 50 meters.

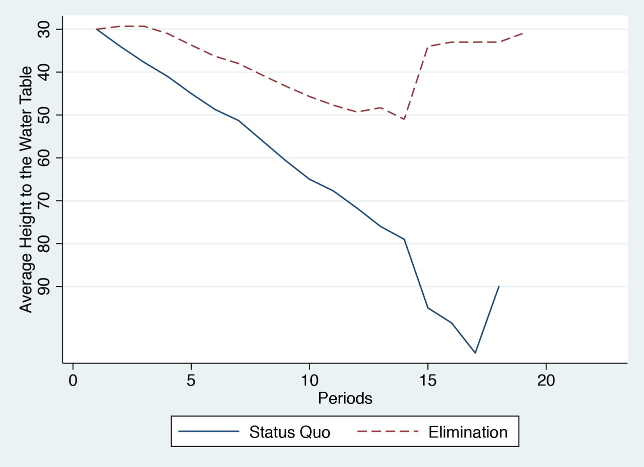


Figure 7. Mean height to the water table (Elimination condition and Status Quo).

Reduction

In the reduction condition, 18 different subjects divided into three groups of six players were instructed to perform the same task as they did previously, except that 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 than in previous treatments. 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 mean requests between the first and second parts of the experiment is not statistically significant.

Figure 9 indicates that, as expected from the previous analysis, the lower extraction decisions had only a minor (and non-significant) effect on the height to the water table. Under reduction, the height to the water table is lower by a factor of almost 2.

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

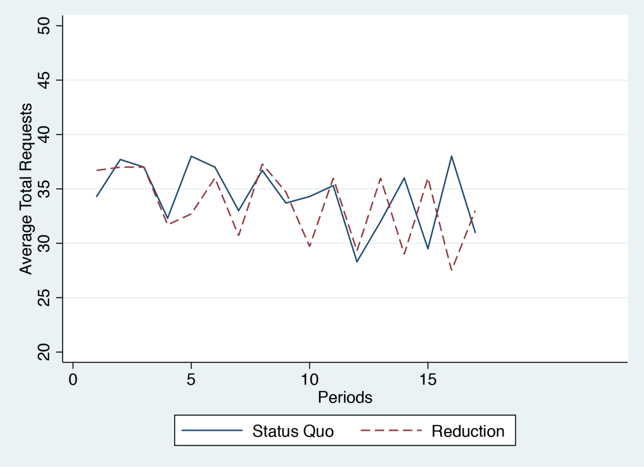


Figure 8. Mean individual requests (Reduction condition and Status Quo) by period.

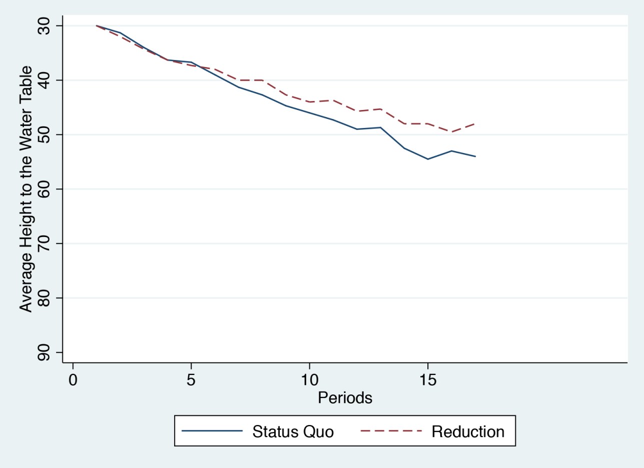


Figure 9. Mean height to the water table (Reduction condition and Status Quo).

decoupling factor and then proceeded to play Part 2, where the subsidy was completely eliminated and replaced by cash transfer.

Figure 10 depicts the mean total request by the group. It shows that the extraction decisions 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 support the theoretical predictions presented in the previous sections more closely than those under any other condition.

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

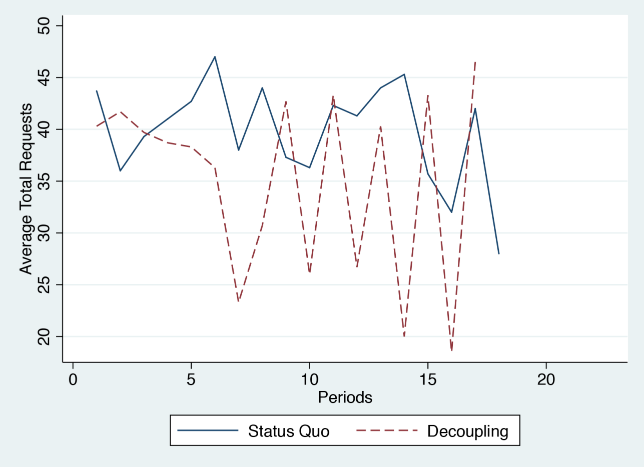


Figure 10. Mean individual requests (Decoupling condition and Status Quo) by period.

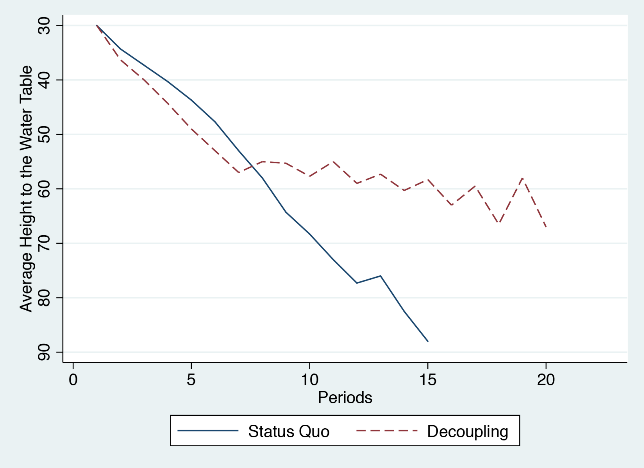


Figure 11. Mean height to the water table (Decoupling condition and Status Quo).

Quantifying policy intervention effectiveness

To examine the effects of the policy interventions quantitatively, we employ the difference in differences method that was proposed by Card and Kroeger (1994). This technique is used often in the literature to analyze the effect of treatment across populations (Cameron 1999; Conley and Taber 2011; List and Rasul 2011; and Collier and Vicente 2014). It compares the behavior of individuals before and after receiving treatment to a counterfactual population. We rely on these works when applying the difference in differences method to our results.

The parameter values of this procedure were estimated by $\Delta u = \beta_1 Pretreatment + \beta_2 Post - treatment + \beta_3 Interaction\ term(pre * post)$, where 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 experimental conditions are presented in Tables 1, 2, and 3 below.

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

Table 1. Difference in differences estimation (elimination condition).

Table 1 shows that, on average, the reduction per period and per individual is 1.58 units of water. This confirms our hypothesis that the sign of the effect is negative. The effect that we observe in the elimination condition is the strongest among all the treatments, which coincides with the theoretical predictions made by Tellez Foster et al. (2017).

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

The treatment effect in the decoupling condition (1.21) is similar to the one calculated for the elimination treatment. It also shows the expected negative sign, and it is close to (but smaller than) the theoretical prediction that states the same effect for the elimination and decoupling conditions.

Robustness of the results

Comparison of the results of the laboratory experiment presented in Tellez Foster et al. (2017) with the results of the field experiment discussed in the present study should lead to a more comprehensive understanding of how policy interventions affect groundwater extraction and, consequently, the height to the water table. The right-hand column of Table 4 presents the treatment effects of the three conditions, calculated by using the difference in differences method.

Table 4 demonstrates that in both sets of experiments (laboratory and field) the sign of the treatment is negative, as predicted by the theoretical model. However, differences in

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

Table 2. Difference in differences estimation (reduction condition).

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

Table 3. Difference in differences estimation (decoupling condition).

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. Difference in differences estimation (decoupling condition).

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 strongest effect, and the reduction had the weakest. A plausible explanation for the differences between the two subject populations attributes them to the experience that the farmers (but not the undergraduate students) had with the problem; therefore, their decisions were closer to the predictions of the model.

Comparison of the two populations

This section compares the results of the experiments conducted in the field with those obtained in laboratory experiments reported in Tellez et al. (2017). The treatment effect resulted in the expected sign for all conditions in both the student and farmer populations. However, significant differences between the two populations have been noted. In particular, as shown in Table 4, the reduction in the mean units of water observed in the farmer population under the elimination condition was twice as large as the reduction observed in the student population. Conversely, under the reduction and decoupling conditions, the same reduction in units of water in the student population was about 60 percent (reduction) and 66 percent (decoupling) higher than in the famer population. Our explanation that attributes these differences to prior knowledge based on prior experience is clearly incomplete as it ignores other differences between the two subject populations in gender (all the farmers were males whereas 50 percent of the students were females), age, and socio-economic status (see Ward et al. 2006).

In addition to the impact of culture, experience, and socio-economic factors on the individual extraction decisions, they also might affect the interactive dynamics within groups. Recall that in both populations subjects were fully informed of the extraction decisions of their group members at the end of each period. This information might have invoked free riding with some group members extracting more water than the group mean with the hope that other group members would compensate by extracting less. One would expect more free riding in the population of undergraduate students, for whom the other group members were mostly strangers, than free riding in the population of farmers, who reside in the same communities, interact with one another periodically, and ought to be more aware of the dire consequences of free riding than the inexperienced students.

To test this hypothesis, we defined free riding for each subject separately as the ratio of the number of periods where he extracted more groundwater than the mean extraction of his group divided by the total number of periods that he played in the session. We conducted a t-test to assess the statistical difference between the two populations of subjects. The test statistically rejected the null hypothesis of equal means (p = 0.0021 by a one-tailed test).

In a subsequent and more robust analysis, we defined a free rider as a participant who extracts more underground water than the mean extraction of his group for at least 50 percent of the periods played by the group. Table 5 shows that the mean number of free riders in the student population exceeded the corresponding mean in the farmer population in each of the three experimental conditions in agreement with our hypothesis.

Condition	Laboratory	Field
Elimination	3.6	2.7
Reduction	3.4	2.3
Decoupling	3.5	2.0

Table 5. Mean number of free riding participants by condition.

Conclusions and policy implications

This study considers the changes in behavior of groundwater users in Mexico under different policy interventions in the context of alternative subsidies to electricity. Its conclusions concerning the implications of policy modifications are briefly discussed below.

Predicted vs. observed behavior

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

In all cases, the farmers demonstrated an understanding of the consequences of modifying the subsidy structure and acted appropriately; their strategies were more aggressive in the first part of the experiment before they adopted a more conservative strategy.

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 the two experiments, both in the laboratory and in the field, jointly 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 a mean reduction of more than one unit of water requested 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 of water requested per period and for the reduction treatment a decrease of less than one unit per period. This result adds to the discussion presented earlier about the differences in the behavior between students and farmers by calling to a further examination of the effects of unobserved factors that might have influenced groundwater extraction.

Our research has demonstrated that changing the subsidy structure for groundwater appropriation has significant effects on the extraction levels and consequent height to 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 first by Muñoz et al. (2006) and later by Tellez Foster et al. (2017), elimination of the subsidy may not always be politically feasible. Reducing the subsidy produces a limited effect (less than one unit of water requested per period on average), and its implementation most likely would face the same political difficulties. Decoupling the subsidy has an effect close to, but somewhat smaller than, the one observed in the elimination condition without the possibly averse political difficulties. Therefore, it would seem sensible to propose decoupling as an alternative policy intervention that might reduce or even completely overcome political obstruction. This, of course, is a topic for a subsequent study that attempts to integrate the economic and political implications of the proposed revision of policy for groundwater extraction.

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