Groundwater and Electricity Consumption under Alternative Subsidies: Evidence from Laboratory Experiments

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Summary:

Pervasive energy subsidies for groundwater pumping pose a challenge for policy makers around the world who cope with lowering water tables from increased reliance on groundwater resources for irrigation. This paper outlines a series of laboratory experiments aimed to study the groundwater extraction decisions of stakeholders under alternative subsidy structures. We propose a model and a methodology for testing the implications of the model and the modification of energy subsidies for irrigation. We analyze the performance of two traditional policy interventions, namely, elimination of the subsidy and reduction of subsidy, and then analyze a novel policy: decoupling of the subsidy from the electricity rate by replacing it with a lump sum transfer. Our experimental results suggest that the rate of water extraction and the level of water in the aquifer, which are undesirable under the existing electricity subsidy, can be significantly improved by altering the subsidy structure. An important finding for policy is that the decoupling leads to similar outcomes as elimination of the subsidy.

1   Introduction

Common pool resource (CPR) dilemmas have been studied extensively in the environmental, biological, and social sciences. In a very influential paper, Hardin (1968) argued that the only possible outcome for selfish individuals who attempt to maximize their expected utility is the collapse of the commons. Traditionally, the two major solutions to his dire conclusion have been the assignment of property rights or the imposition of governmental regulations (Ostrom, 1990). Groundwater as a CPR is subject to these solutions. Governments and policy makers around the world have been trying to solve the problem of overexploitation of aquifers while at the same time trying to guarantee quality supply of this resource. Too often they have not been successful. Several misguided or poorly designed policies have exacerbated the tragic outcome prophesized by Hardin (1968) by providing the wrong incentives to users for the extraction of groundwater. This has been the case of energy subsidies for pumping groundwater, where the artificially reduced cost of pumping the water has fostered the overexploitation of aquifers and exacerbated the negative externality generated by their users.

Reforms in the water and energy sectors are often costly economically and difficult to implement politically. Therefore, generating methods for testing them in a reliable and replicable way is needed so that inferences may be drawn about the potential results of implementing alternative policies. Experimental economics provides procedures for analyzing these policy and institutional changes in a very cost effective way (Murphy et al, 2000).

This paper analyzes the impact of elimination, reduction, and decoupling of the subsidy for electricity from the demand for groundwater, derives testable hypotheses, and then chooses parameters for testing these hypotheses on the basis of the results from the simulations proposed in Tellez Foster et al. (2016). Our approach calls for implementing a CPR dilemma game in the laboratory, where participants make a series of inter-temporal production decisions (the amount of water pumped for agricultural production) and subsequently receive monetary payoff contingent on the water table level. The pumping costs are negatively related to the height to the water table, so that the more water is pumped, the deeper is the water table and, consequently, the more electricity is required for pumping therefore increasing the pumping costs.[1] The water table level is lagged by one period so that the players face an inter-temporal optimization problem.

Our proposed experiment is similar to the one introduced by Fischer et al. (2004), who used a growth model to simulate the rate of regeneration of the resource. Fischer et al. (2004) include four generations of three subjects each. Our experiment differs from theirs because it includes no generations of players; rather, the same subjects participate in all periods, and the resource stock in period t depends on the stock level in period t-1. The model used to predict the strategies is similar to the one proposed by Salcedo et al (2013), who introduce a dynamic optimization model which sums the present value of net benefits over several periods of time, and where the equation of motion describes the height to the water table that

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[1] Since we are only interested in the amount of revenue from irrigation water, the payoff does not depend on the production level. Extensions of the model could include production level, type of crop, and price of crops as other determinants for water consumption.

depends on the collective action of the users and the height to the water table in the previous period.

Suter et al. (2012) developed a dynamic model that includes spatial relations based on the position of the wells and their implications for the exploitation of groundwater. They include physical and geological relations to ensure that the model is as realistic as possible. Our study accounts for the changes in behavior when the users face various increases in the price for electricity, which are compensated by a monetary transfer or a subsidy of another kind.

2   Literature Review

There exists a substantial body of literature that explores CPR problems from the experimental economics perspective. This is due to the fact that, as discussed before, changes in the management of such resources are costly, slow, and in many cases irreversible. Therefore, experimental economics provides policy makers with sound and robust evidence that might give rise to changes in policy towards the better management of such resources.

Fischer et al. (2004) report an experiment in which subjects were asked to extract water from a CPR with a known regeneration rate over a horizon of four generations. They concluded that, in general, subjects expected other participants to extract less, and that there was always a temptation to free ride. On the other hand, Suter et al. (2012) explored the relationship between the decisions made by stakeholders on the amount of groundwater extracted when the physical characteristics of an aquifer are taken into consideration. They reported that when farmers realize that the effects of exploiting the aquifer (social costs) exceed their own private costs (due to the cone of depression created by pumping), they tend to approach the

optimal extraction rate. Ward et al (2006) compared results from the lab and the field in a groundwater extraction experiment and reported that the results were comparable in both cases. Their study is relevant to our research as it compares the effects of a policy manipulation with subjects in the lab and stakeholders in the field. In another set of studies, Botelho et al. (2014) analyzed the effect of time and uncertainty in CPR dilemmas, finding that across all treatments CPR users often make decisions that lead to the depletion of the resource (or terminate the game immediately). In another study, Botelho et al (2012) analyzed how property rights and the provision of public goods affect the depletion rate of CPR, finding that appropriation and the option of contributing to the preservation of the common resource are substitutable actions for reducing the rate of destruction of the CPR and may explain the emergence of tacit cooperation in the common resource dilemma.

Murphy et al. (2000) conducted a series of experiments with highly sophisticated software that calculated in real time equilibrium prices and allocations for trade in water rights. These experiments were designed to test the mechanism of "smart" water markets in which, with the aid of technology, efficiency could be achieved and the highest benefits from trading could be extracted. Their conclusions state that the design of water markets with the aid of technology could help achieving efficiency at a reasonable cost.

The aforementioned literature has not explored the effects in subjects' behavior when subsidies for extraction are modified in a CPR dilemma context. Our proposed experiment is designed to study how agents make extraction decisions based on the level of subsidy to electricity for pumping groundwater. This implies that the cost of extracting groundwater

varies not only according to the water table but also according to the subsidy mechanism in each treatment.

3   A model of Groundwater Extraction

The model that we consider in this section follows Provencher and Burt (1993), and the functional form of the profit function follows Salcedo and Gutierrez (2013). The aquifer considered here is a boxed-shaped, and the pumping cost function is linear in the height to the water table as the state variable. The farmers (players) are assumed to be homogenous with a single crop and same farm size.

The benefit function for pumping groundwater for farmer j at period 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}, by farmer j at period t; γ is the subsidy to electricity for pumping groundwater; P_E is the price for electricity; and ξ is the amount of electricity required to pump one cubic meter of water to a height of one meter. As mentioned earlier, the cost function is linear in the height to the water table following the modification of Provencher and Burt (1993) made by Salcedo and Gutierrez (2013). In our model, $\bar{X}$ is the maximum height of the aquifer; x_t is the height to water table at period t; A is the area of the aquifer; S is the storativity; and AS is the volume of the aquifer available for storing water. C_0 is the fixed cost of pumping; it is generally associated with installing and maintaining pumping equipment.

The equation that relates users' behavior at period t with the pumping conditions in the next period is given by:

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

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 AS.

The model maximizes the present value of net benefits (profits) over an infinite periods horizon. Two types of users are considered here independently, a myopic user, who does not take into account the cost imposed on other users because of his actions or the costs he imposes on his own future profits, and a strategic user, who makes an extraction decision based on the other users actions.

Myopic users are assumed to adopt the common property strategy; they are called *myopic* because they choose to pump the maximum amount of water as long as the benefit of doing so is positive. Therefore, the myopic user strategy, u_{mt},[2] is represented by:

$$u_{mt} = \begin{cases} \overline{u_t} & when \quad x_t \leq \bar{X} - \frac{\gamma P_E \xi}{AS\delta}, \\ 0 & otherwise \end{cases} \qquad (3)$$

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[2] The subscript m stands for myopic user.

where $\overline{u_t}$ is the maximum amount of water per period that the myopic user pumps as long as

the condition $x_t \leq \bar{X} - \frac{\gamma P_E \xi}{AS\delta}$ is satisfied.

The behavior of the strategic user may be described by the dynamic optimization problem:

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

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

where J is the number of users extracting groundwater from the aquifer.[3]

We may then write the Bellman equation:

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

The Bellman equation breaks down the infinite horizon problem into a two-stage discounted

function that we use to derive the optimal path of extraction.

From the Bellman equation we can derive the first order conditions that yield the following

Euler Equation:

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

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

The Euler equation is used to derive the optimal path of extraction. In our equation, systematically increasing the value of gamma from 0 to 1 increases the cost in the present $\frac{\gamma P_E \xi}{(\bar{X}-x_t)AS}$, but also increases the marginal (discounted) benefit in the future $\frac{J\delta - \left(\frac{J\gamma P_E \xi}{(\bar{X}-x_{t+1})AS}\right)}{\frac{J}{AS}}$.

Therefore, we may anticipate that changes in the subsidy will lead to a deviation in the optimal extraction path that, in turn, will further lead to a better steady level of the state variable.

We proceed with testing the behavior of the model under status quo conditions ($\gamma = 0.2$, meaning a subsidy level of 80%), using parameter values from Salcedo and Gutierrez (2013) and the Matlab package CompEcon by Miranda and Fackler (2002). The results are exhibited in the next set of graphs:

Figure II.1 Optimal Value Function and Optimal State Path under Status Quo
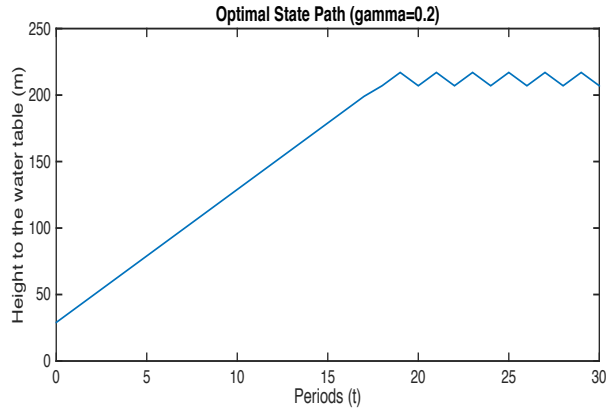

Figure 1 shows that the height to the water table increases and reaches a steady state around period 20 and then continues *zigzagging* across the remaining periods. This *zigzaging* is explained by the fact that the users switch on each period from the maximum extraction level to zero because the recharge rate makes it profitable to extract groundwater on every other period after the steady state is reached.

4 Policy Interventions

So far we only have analyzed the users' behavior when given an electricity subsidy for pumping groundwater. In this section, we examine the effects of three different policy interventions, namely *elimination*, *reduction*, and *decoupling* of the subsidy. To analyze the first two, we simulate the users' response by varying the value of γ from 0 to 1 in increments of 0.1. For this analysis, we use the parameters in the study by Salcedo and Gutierrez (2013) of users' behavior to pumping groundwater in the region of Aguascalientes, Mexico. We also use the CompEcon toolbox for Matlab developed by Miranda and Fackler (2002). The model

in our analysis was simulated for one hundred periods, varying the parameter γ from 0 to 1 in 0.1 increments.

Figure 2 shows that the steady state of the height of the water table increases as the level of subsidy increases. This suggests that the subsidy to electricity influences the amount of water pumped from the aquifer resulting in deeper steady state levels for higher rates of subsidy.

Figure II.2 Height to the Water Table for Different Subsidy Levels
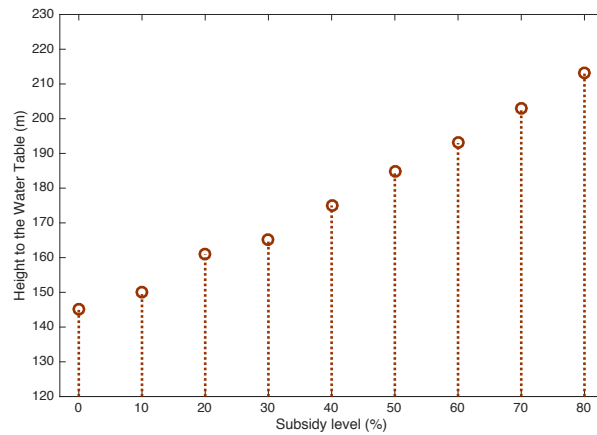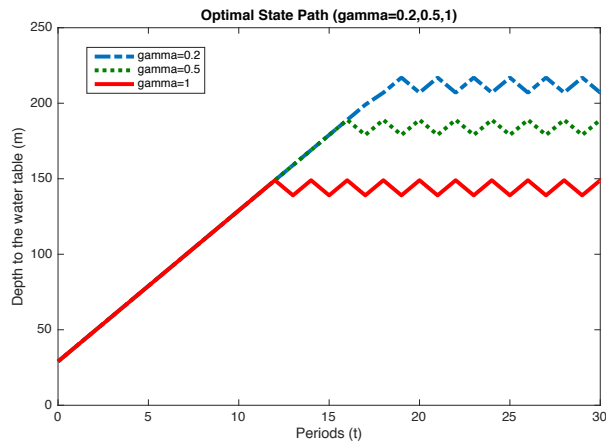

Figure 3 shows the level of the steady state for three different levels of gamma. Once again, we observe that the highest levels of subsidy lead to a deeper levels of the water in the aquifer; furthermore, the time of convergence to the steady state is longer for higher levels of subsidy.

Figure II.3 Optimal State Path for Different Values of Gamma

One of the most relevant aspects to policy makers is finding out which policy achieves a less deeper steady state in the shortest time possible. Figure 4 shows how many periods it takes to achieve the steady state at each level of the subsidy.

Figure II.4 Time of Convergence to Steady State
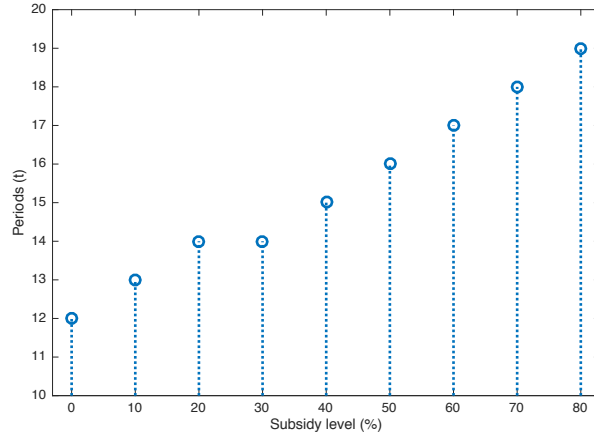
The third policy instrument to be tested is the decoupling of the subsidy from the electricity subsidy. In this case, users receive a transfer equivalent to their consumption during the last i periods.[4] The optimization problem in this case is:

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

The Bellman equation takes the form:

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[4] i is the number of periods considered for calculating the mean consumption; it ranges from 1 to t-1 for all t>2.

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

The optimization problem is similar to the optimization problem presented in last section,

although we include the decoupling to the electricity subsidy $\frac{\sum_{k=t-i}^{t} \frac{u_k \gamma P_E \xi}{(\bar{X} - x_k)AS}}{i}$, which is the

mean consumption of the last i periods ($i > 0$).

As with the first optimization model, we use the Bellman equation to derive an Euler equation

that sheds light on how the behavioral responses to changes in the subsidy affect the optimal

path:

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

This equation shows that the term $\frac{\gamma P_E \xi x_t}{i}$, which represents the marginal change in the

decoupling transfer due to changes in the level of subsidy (γ), keeps the equation balanced

as it is added on both sides of the equation to the costs and benefits. Based on this, we expect

that the behavior of the users under decoupling will follow the same or will be very close to

the behavior under the elimination instrument.

The hypothesis to be tested in our experiments is that changing the incentives by eliminating

the subsidy, or instead by giving the users a cash transfer decoupled from the subsidy, results

in a decrease in the amount of water pumped and in a higher steady state level of the water table.

The results portrayed in Figure 5 represent a comparison between status quo, subsidy reduction from 80% to 50% rate, and 15 period for calculating the mean decoupling factor. Decoupling is seen to accomplish a steady state of the height to water table that is lower than reducing the subsidy to 50 percent. These results suggest that decoupling is a viable policy intervention.

Figure II.5 Optimal State Path for Different Policy Interventions
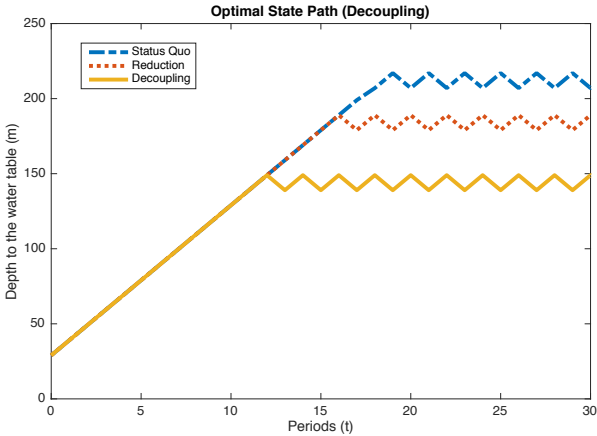
As stated earlier, the optimal strategy for myopic users is to extract the maximum amount of water possible (in our case we set a limit of 10 units) until it is no longer profitable to extract water. Figure 6 exhibits the extraction path for the cases of decoupling and status quo (elimination and reduction follow the exact same path as decoupling when we consider that myopic users only care about maximizing the current period profit).

Figure II.6 Extraction Path Comparison: Status Quo vs. Decoupling
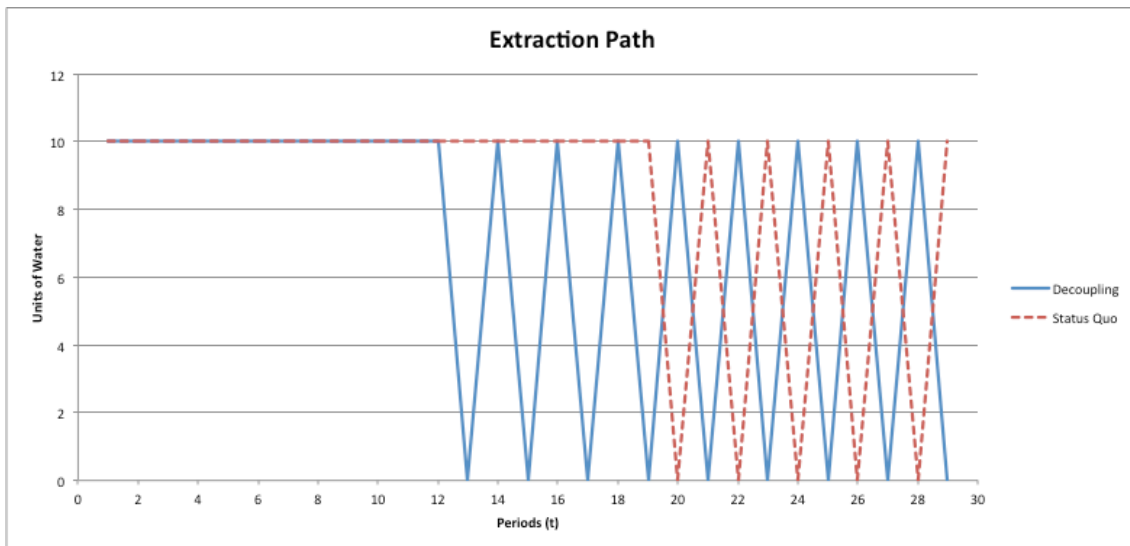
The behavior exhibited in Fig. 6 explains why the steady state of the height to the water table fluctuates over periods. Once a certain height is reached, it is not profitable to extract water; however, the recharge rate makes extraction profitable again in the next period.

5   Laboratory Experiments

We tested the analytical results in the laboratory. To ensure robustness and statistical power of the experiments, we recruited for each condition five groups of six members each. The total number of subjects recruited for the four conditions was 120. All the subjects for each of the three policy interventions first played the Status Quo (Condition 1), and then proceeded to play the policy intervention (Reduction, Elimination, or Decoupling). The control group played Status Quo in both parts of the experiment.

The subjects were randomly assigned to groups. No communication was allowed during the experiment.

The experiments were conducted in a large laboratory. Subjects were seated in individual cubicles that prohibited communication. They were recruited through an automated on-line system from a pool of all undergraduate students on the University of California Riverside campus; none of the students had participated in similar experiments before. Sessions lasted no longer than two hours, including check-in and payment time. The procedures for the five conditions are summarized below.

Condition 1: Status quo (no changes to the subsidy).

Subjects in this condition were instructed to request an amount of water to be pumped from the aquifer. The water table level at the beginning of each period was commonly known by the group members. Subjects were provided with a schedule that listed the profits for each combination of height to the water table and the set of possible requests. Once they submitted their requests, the subjects proceeded to the next period where they were informed of the new height to the water table. The extraction game had an infinite horizon; each round was terminated randomly with probability p set at $p = 0.15$[5] or continued for at least one more period with the complementary probability of 0.85. At the end of the session, subjects were paid contingent on their performance (profits are stated in tokens).

Condition 2: Reduction of subsidy.

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[5] This is following the experimental procedure for infinite horizon used by Suter et al. 2012.

Subjects in this condition were instructed to request an amount of water to be pumped from the aquifer. They faced a reduction of the amount of subsidy (from 80% to 50% of electricity price subsidized). As in Condition 1, they were informed of the height to the water table and the profit conditional on the aggregate request.

Condition 3: Elimination of subsidy.

Subjects performed the same task as in Conditions 1 and 2 with the same per period termination probability of 0.15. For this condition, the subsidy was completely removed (setting $\gamma_t = 1$).

Condition 4: Elimination of subsidy and transfer of payment (Decoupling)

In Condition 4, the subjects performed the same task as in Conditions 1 and 2. However, after 15^6 consecutive periods they were told that the subsidy would be removed (setting $\gamma = 1$), that their individual mean subsidy would be calculated, and that they would be granted a token transfer equivalent to the subsidy they received during the first 15 periods of the first part (Condition 1).

Condition 5: Control

In Condition 5, the subjects performed the same task as in Condition 1. After the random termination of part 1, they proceeded to play the same game as under Condition 1 (status

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[6] We use 15 periods to reduce bias for periods of high requests or low requests as explained in Tellez Foster et al (2016)

quo) with the same subsidy level ($\gamma_t = 0.2$) until it was randomly terminated. This condition was conducted in order to gather data on subject behavior under no treatment so that we could establish a baseline for comparing and calculating the treatment effects of the previous three treatments.

6 Results

We compare below only the results of Condition 1 with the policy treatment conducted in each of the other conditions; we do not compare the status quo results across conditions. These results are not compared due to the different characteristics of each group to being exposed to status quo and to the treatment, the difference in difference technique entails the comparison of groups pre and post treatment but not cross comparison between pre treated groups and post treated groups.

6.1 Elimination

For the elimination condition, we recruited 30 undergraduate students to form five groups of six members each. Subjects read the instructions at their own pace. This was followed by a brief oral summary and a short question and answer period. This same procedure was implemented for all conditions.

In this sub-section, we compare group results in the 'Status Quo' and 'Elimination' conditions. Figure 7 exhibits the mean total requests across groups for these two conditions. It shows that as subjects adapt to the policy change in periods 1-3, they play the strategy that they used consistently in part 1 of the experiment (Status Quo Condition). As they realize that pumping becomes more expensive, they lower their requests consistently.

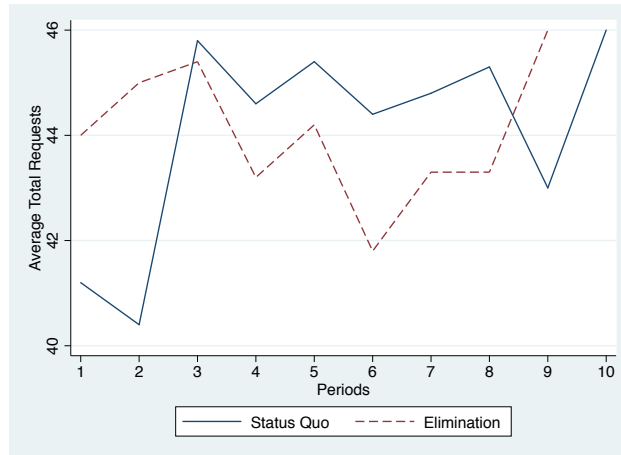**Figure II.7 Mean Total Request by Group. Condition: Elimination**

Figure 8 displays the mean height to the water table across groups. The mean height to the water table in Status Quo Condition is consistently but slightly lower up to the 7th period. In the last two periods this trend is reversed, and the height to water table for the Elimination Condition stabilizes whereas the one for Status Quo Condition accelerates.

Figure II.8 Mean Height to the Water Table. Condition: Elimination
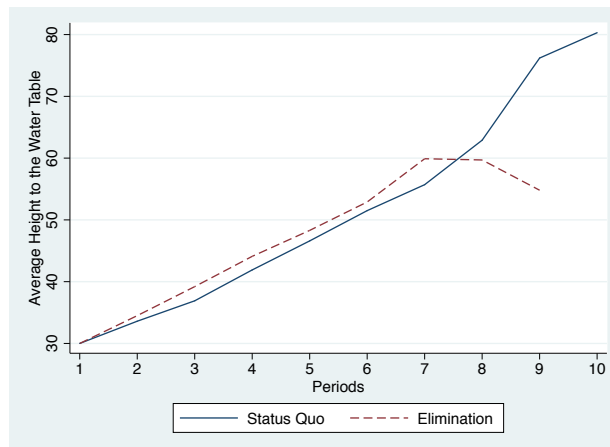
6.2 Reduction

The subjects in the Reduction Condition were instructed to perform the same task as in Condition 1 except that in this case they faced a reduction in the subsidy from 80% to 50% (changing $\gamma = 0.2 \ to \ \gamma = 0.5$).

Figure 9 illustrates the mean request for the Status Quo and Reduction Conditions. With the exception of round 9, mean requests across groups for the Status Quo Condition were relatively stable across periods, ranging from 44 to 50. In contrast, subjects in the Reduction Condition increased their requests steadily across the 13 periods from 36 to 55

Figure II.9 Mean Total Requests per Group. Condition: Reduction
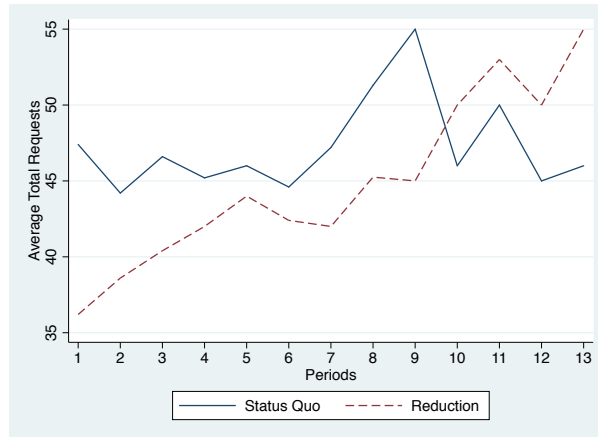
The effect of the change in policy is displayed in Fig. 10. The mean height to the water table across groups is consistently lower in the Reduction Condition compared with the Status Quo Condition although the difference between these two conditions never exceeds 11 meters.

Figure II.10 Mean Height to the Water Table. Condition: Reduction
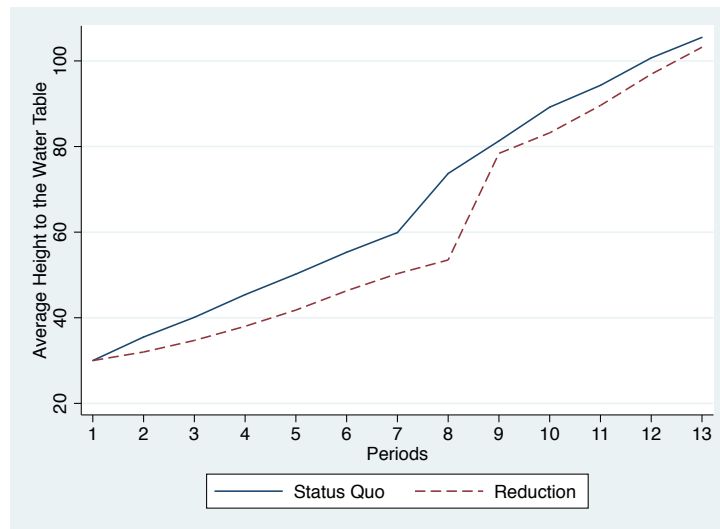
6.3   Decoupling

The procedure in the Decoupling Condition was similar to the procedure in the previous two conditions. The major exception was that the requests were recorded and at the end of period 15 (part 1 of the experiment) the mean cost was computed and each subject was informed that the subsidy had been removed and replaced by a token transfer (lump-sum subsidy). The token amount was equivalent to the mean individual request in part 1 of the experiment; it was granted at the end of each subsequent period in part 2 regardless of the requests in part 2 of the experiment.

The effect of decoupling the subsidy is the strongest among all conditions, we observe in Figure 11 that the average request per group is significantly lower once the subsidy is decoupled. This is reaffirmed when we observe the behavior of the height to the water table in Figure 12, where it is evident that once the subsidy is decoupled, the pace at which the aquifer becomes deeper decreases creating a gap between the height to the water table under status quo and decoupling.

Figure II.11 Mean Total Requests per Group. Condition: Decoupling
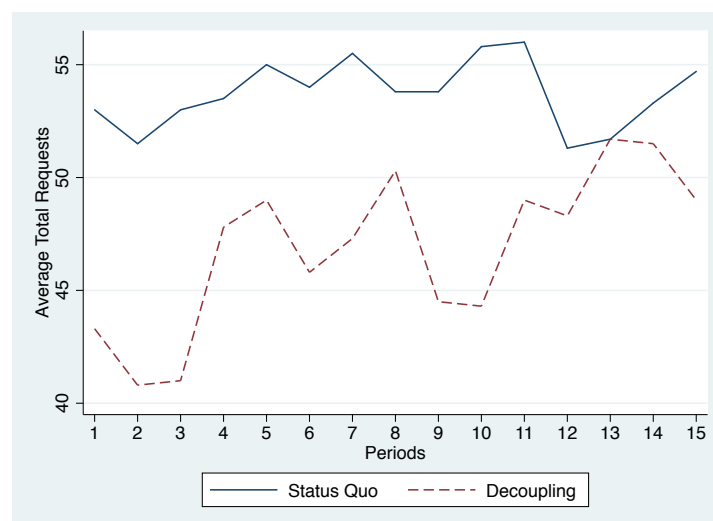
Figure II.12 Mean Height to the Water Table. Condition: Decoupling
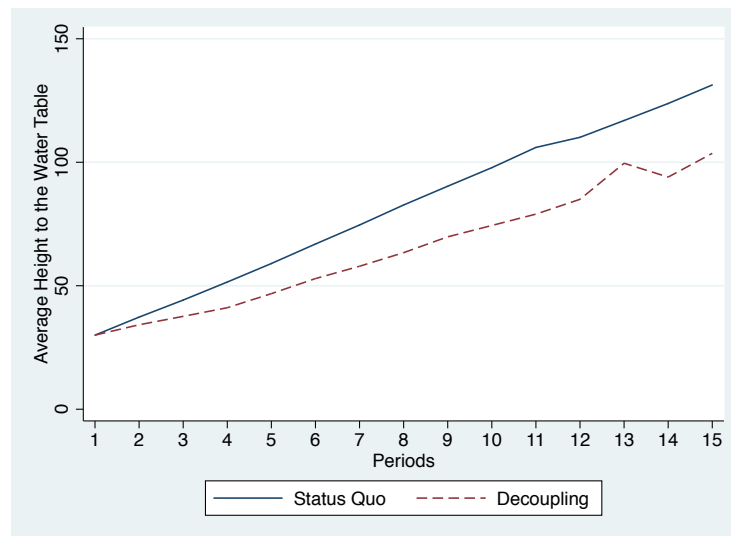
6.4 Control

For purposes of comparison we also ran a control experiment in which students played

status quo condition in both parts, with the same procedure as with the previous conditions

as seen in Figures 13 and 14. The results suggest that subjects tend to play more aggressive

in the second part of the experiment after learning how to play. The observations of this

experiment allowed us to capture any unobservable variable that may affect the requests so

we can calculate more accurately the treatment effect.

Figure II.13 Average Total Requests per Group
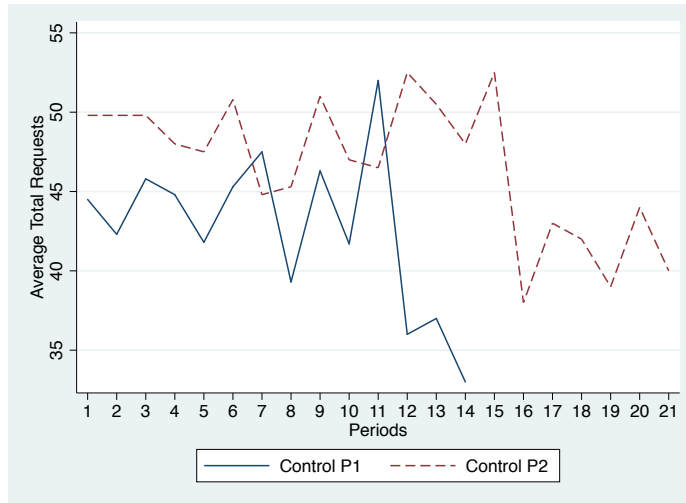
Figure II.14 Average Height to the Water Table
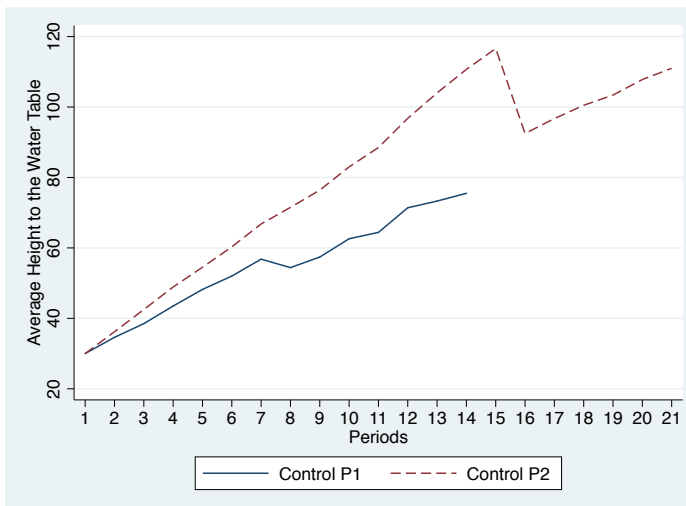
7 Effectiveness of the Policy Interventions: An Econometric Analysis

In this section we analyze the treatment effect of each condition, we provide a quantitative analysis of the behavior of participants under different conditions and we use this results as a base for drawing policy implications. For the purpose of this experiment we will use the difference in difference method since it allows us to compare the difference in extractions under the different conditions.

The "difference in difference" estimation method is a common technique used in the literature to determine the effect of treatment across individuals with similar characteristics that use counterfactual scenarios to observe the behavior of individuals that have not received the same treatment and compare it to the individuals who did.

This technique has been widely used in the economic literature with its flagship work by Card and Krueger (1994), where they estimate the effect of employment after the increase in minimum wage in New Jersey. We chose the "difference in difference" method to compare the effectiveness of the policy interventions. We estimated a series of econometric models that attempt to capture quantitatively the effect of change in subsidy level on the requests for water.

To ensure sound and robust estimations, we repeated this process 1000 by bootstrapping from a uniform distribution for the random drawings. We then estimated the effects of treatment using the following model:

$$\Delta w = \beta_1 \, Pretreatment + \beta_2 \, Posttreatment + \beta_3 \, Interaction \; term \; (pre * post)$$

where Δw is the change in the requests for water after the treatment is applied, β_1 is the estimator for the status quo (Pretreatment) condition, β_2 is the treatment estimator and β_3 is our relevant estimator where we obtain the final effect of the treatment.

We present the estimations for the three treatments in three separate tables:

Table II.1 Treatment Effect Estimation. Condition: Elimination

Number of observations in the Diff-in-Diff: 1032

	Baseline	Follow-up	
Control:	246	318	564
Treated	234	234	468
	480	552	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	7.264			
Treatment (T)	7.333			
Diff (T-C)	0.069	0.249	0.28	0.781
Follow-up				
Control (C)	8.041			
Treatment (T)	7.321			
Diff (T-C)	-0.720	0.235	-3.07	0.002***
Treatment effect	-0.789	0.342	-2.31	0.021**

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

Table 1 shows that the sign of the treatment effect is negative and statistically significant as expected, revealing that eliminating the subsidy reduces the requests by, 0.789 units of water per individual, on average, for each period. Even though the effect is small, it is the cumulative effect of each diminished request that yields a better outcome as compared with the status quo condition.

Table II.2 Treatment Effect Estimation. Condition: Reduction

Number of observations in the Diff-in-Diff: 1086

	Baseline	Follow-up	
Control:	246	318	564
Treated	258	264	522
	504	582	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	7.264			
Treatment (T)	7.810			
Diff (T-C)	0.546	0.226	2.41	0.016**
Follow-up				
Control (C)	8.041			
Treatment (T)	7.053			
Diff (T-C)	-0.988	0.211	-4.68	0.000***
Treatment effect	-1.534	0.309	-4.96	0.000***

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

In the reduction treatment, Table 2 shows a stronger effect as when compared to the control group. In this case, we observe that the subjects reduce their request on average by 1.534 units per period. This result does not coincide with our initial prediction, where the reduction condition treatment effect seemed smaller as compared to the other two conditions, however, the sign is negative as expected and statistically significant.

Table II.3 Treatment Effect Estimation. Condition: Decoupling

Number of observations in the Diff-in-Diff: 1224

	Baseline	Follow-up	
Control:	246	318	564
Treated	336	324	660
	582	642	

	Request	S. Err.	t	P> | t |
Baseline				
Control (C)	7.264			
Treatment (T)	8.979			
Diff (T-C)	1.715	0.195	8.79	0.000***
Follow-up				
Control (C)	8.041			
Treatment (T)	7.741			
Diff (T-C)	-0.300	0.183	-1.64	0.10*
Treatment effect	-2.015	0.268	-7.53	0.000***

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

The decoupling treatment (Table 3) yielded the greatest effect among all conditions, with a reduction in the average request per subject of 2.015 units. This result indicates that subjects reacted more forcibly to decoupling the subsidy than to the reduction or elimination. This result may be explained by a change in their behavior to a more conservative strategy after receiving the transfer lump-sum every period.

8 Conclusions and Policy Implications

This paper analyzes the effects of different subsidy structures and policy modifications on sustainability of GW, given the perverse incentives of electricity (or more generally, energy) subsidies for GW pumping in the farming sector. By embedding the subsidy into the cost function we could measure the effect of different policy interventions. Our analysis gives rise to several conclusions that are reported below with respect to various institutional arrangements and different policy interventions.

Comparing predictions with experimental results

By comparing the observed behavior of the subjects to the predicted behavior we find that all three policies have a negative effect on the water requests; however, decoupling the subsidy has a stronger effect among the three in support of our hypothesis that this intervention yields the most desirable results.

It is worth mentioning that even though the theoretical predictions indicated that elimination and decoupling should have similar effects, we observe that the former had the least effect among the three conditions. This result might be explained by the more conservative strategy followed by subjects during the first part of the experiment, which captured a smaller effect when compared to reduction or decoupling the subsidy.

In the Reduction Condition, subjects chose a more aggressive strategy in the first part of the experiment, and when they faced a reduction in the subsidy they switched to a more conservative approach. It is worth noting that the group's behavior across treatments was very different when playing Condition 1. This means that some groups acted more conservatively in the first part of the experiment, as seen in the Elimination Condition, while other groups acted in a more aggressive manner, as seen in Reduction and Decoupling Conditions. This has to do more with the subject expectations of their group's behavior than with the design of the experiment.

Policy Implications

The joint results of the simulations and experiments suggest that we may expect a reduction in the water pumping by farmers when the subsidy is modified by reduction, elimination, or decoupling. The importance of this finding is that, given the political power that farmer organizations bear and the strong lobby they mobilize, it is politically infeasible to simply eliminate the electricity subsidy. Therefore, we propose a different policy alternative to address this problem with lower social/political cost. Our results support the conclusion that decoupling is a feasible policy modification for achieving the stabilization of over-drafted aquifers. In addition, decoupling would have similar effects as drastically reducing or eliminating the subsidy with a much lower political burden than the latter policies implicate.

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