Cooperation makes it happen? Groundwater management in Aguascalientes, Mexico: An experimental approach

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COOPERATION MAKES IT HAPPEN? GROUNDWATER MANAGEMENT IN AGUASCALIENTES: AN EXPERIMENTAL APPROACH[*]

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Abstract

This research develops economic framed field experiments in order to analyze the attitude and behavior of farm groundwater users in several fictional situations, including adoption of efficient irrigation technology and compliance of group arrangements. A groundwater game was played by 256 farmers selected from different regions of the state of Aguascalientes, Mexico.

Key Words: Common pool resource management; groundwater; efficient irrigation technologies; strategic behavior; behavioral economics; economic framed field experiments, Latin America.

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1 Introduction

Economists and political scientists have devoted great effort to understand how common pool resources (CPR) are managed, as well as the characteristics of the institutions that emerge in order to deal with the use and distribution of CPR (see McGinnis, 2000). CPR can be defined as goods that, because of their natural characteristics, exclusion is difficult but agents can appropriate part of it, and that part of the resource is no longer available for another person's use (Ostrom and Gardner, 1993; McGinnis, 2000). Because of the peculiarities of this kind of resources, traditional microeconomic theory predicts that the rent-seeking behavior of individuals yields overexploitation and further depredation of the good, as explained by the "Tragedy of the Commons" presented by Hardin (1968). Besides the traditional solutions to the problem (clear property rights and government intervention), recent scholars have developed research that analyzes the importance of collective action and the role of the community on the management of CPR (Coward, 1976; Ostrom, 1986, 1990, 1992; Ostrom and Gardner, 1993; Trawick, 2003). These scholars argue that rules that are internally created and agreed by the community, along with a set of tools that ensure the enforcement of those rules, are more effective in the provision and preservation of CPR (Ostrom, 1990; Ostrom and Gardner, 1993; Dayton-Johnson, 2000; Trawick, 2003; Swallow et al., 2006). These studies have found some evidence that cooperation among the users of a CPR can emerge, and that face-to-face communication between the agents is important to ensure compliance of the rules (Hackett et al., 1994; Cárdenas, 2011; Moreno-Sánchez and Maldonado, 2010). On this regard, the characteristics of the system and the way how agents interact within the system is important for the success of the community as an institution that ensures the sustainable and responsible exploitation of the resource. Moreover, the dynamics of the system and the way how CPR users make decisions in this setup is important. In a recent study, Madani and Dinar (2012) asses the performance on various types of non-cooperative institutions. Using numerical simulations they find that groundwater users that have flexible long term plans and consider the externalities generated by other users improve their gains, as opposed to rigid short-term plans with no consideration of the externalities. Then, it is important to understand the conditions working for and against sustainability of local cooperation in situations of general social and economic interdependence (Bardhan, 2000).

This research will develop economic framed field experiments with a sample of farmers of Aguascalientes in order to observe the attitude and behavior of water users on the appropriation of water and analyze the factors that facilitate or inhibit cooperation under different fictional situations. More specifically, the objectives of the research can be enumerated as follows:

i. To analyze the behavior of water users towards the use of groundwater for agriculture and the investment in efficient irrigation technologies, considering the potential strategic behavior that may arise and the role of these technologies on groundwater conservation,

ii. To analyze the performance of group arrangements in the improvement of the use of water and endorsement of appropriation levels that yields a socially-desirable economic outcome.

The document is organized as follows: In the next section, we briefly mention the nature of the problems related to water in Aguascalientes, Mexico. Then, we discuss current models related to groundwater management. In Section three we present the experimental design and the structure of the sessions that we conducted in Mexico. Section four presents the analysis, including the treatment effects, comparisons with theoretical outcomes and dynamics, and Section five concludes.

2 Water problems in Aguascalientes

The state of Aguascalientes is located in a semi-arid area in Central Mexico. Water from rain is only available during the rainy season between May and September with an annual rainfall of 500mm/year. In 2007, 50,542 has. were irrigated, which represent 30 percent of the total agricultural area in the state, and is also the most productive land (INEGI, 2009). From the irrigated agricultural areas, 36 percent receives water from dams and 67 percent is irrigated with groundwater[1]. The main problem in Aguascalientes is the overexploitation of the aquifer Ojocaliente-Aguascalientes-Encarnacin (OAE), which is currently the main source of water of the state. The estimated annual net use of groundwater in the watershed of Aguascalientes, which is the most important agricultural area in the state and also hosts the capital city - the city of Aguascalientes- is 433 million m3/year, from which 71 percent of this volume is used in agriculture, 22 percent in urban purposes, 1.6 percent is used for industrial purposes, 5.7 percent is devoted to other uses and natural losses (COTAS, 2006). However, the estimated annual recharge of the aquifer (natural recharge and filtrations from dams and superficial irrigation) is 234 million m3/year. Therefore, there is a deficit in the use of groundwater of 199 million m3/year which is not replenished, and the ratio of extracted water/recharged water is 1.9, meaning that the water that is consumed is almost twice the water that is recovered (COTAS, 2006). The problem is evident when looking at the depth at which water is extracted. As shown in Figure 1 the average depth-to-water increased from an average of 33 m. in 1965 to 87 m. in 1985 to 145 m. in 2005 (Gobierno del Estado de Aguascalientes, 2009). Also, currently there are 3,285 wells from which 1,539 are for agricultural purposes (privately and collectively owned). Moreover, the supply of water per capita is 281.6 m3/year, which is considered extremely low for international standards (Gobierno del Estado de Aguascalientes, 2009).

A potential solution to the overexploitation of the aquifer is the installation of efficient irrigation systems on the parcel. However, as noted by several authors, the impact of the adoption of these systems on the reduction of the depletion of the aquifer per se is ambiguous. Moreover, there is some evidence that the farmers of the area of analysis are reluctant to the adoption of these technologies (Caldera, 2009). Also, the government is developing capacity building programs with the Water User Associations (WUA) of the region. Given this setting, it is crucial for the authorities and researchers of Aguascalientes to investigate about the attitude of farmers in Aguascalientes towards the use of water for agriculture and the adoption of more efficient technologies, not only as mechanisms that might improve private yields, but also as a water saving methods; and to analyze the role of organization and internal agreements among users in the improvement of groundwater management in Aguascalientes.

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[1] Percentages do not add because many farmers receive water from both sources

3 Prior research

3.1 Groundwater allocation and CPR

Groundwater management was not analyzed as a problem in Economics until the seminal work of Burt and Brown and Deacon (Burt, 1964, 1967, 1970; Brown and Deacon, 1972). These authors apply individual privately owned non-renewable natural resource models to solve the centralized controlled problem, in which inefficiencies from externalities in water extraction are fully internalized by users. Later, economists started to treat the groundwater situation in a competitive (no control) setup. In this approach, groundwater users' behavior is myopic, where no consideration of the "use value" of water is taken into account, and the current marginal value of water is equalized to the current marginal cost of water extraction (Gisser and Sánchez, 1980; Nieswiadomy, 1985; Worthington et al., 1985, see). Most of these studies conclude that the optimal path in the controlled and the competitive situations is the same, implying that there are no welfare gains from a controlled optimal allocation of groundwater. This result is usually referred as the Gisser-Sánchez effect. However, as pointed out by Koundouri (2004a,b), there are reasons to believe that the conclusions of Gisser and Sánchez should be taken with caution, since several assumptions about the nature of the aquifer, functional forms and heterogeneity of agents are made. When these assumptions are relaxed, the features of the Gisser-Sánchez effect do not necessarily hold.

Later, economists began using game-theoretic features to develop groundwater analytical models. The major focus of this group of studies was to analyze the behavior and interactions among water users given the strategic behavior that might arise in different situations, as well as the welfare losses due to strategic behavior. These studies usually focus on the sources of inefficiency based on three types of externalities generated by the appropriation of the resource (Gardner et al., 1990): i) Stock (Cost) Externalities, that arise when changes in the stock of the resource affect the cost of extraction of the resource to all users; ii) Strategic Externalities, related to the common-property feature of the resource and the difficulty of property rights allocation, which might encourage users to extract more than optimal level of the resource because of fear of appropriation of the scarce resource from other users in the future (Negri, 1989); and iii) Congestion Externalities, related to the spatial distribution of the points of extraction of the resource. Provencher and Burt (1993) also identifies, iv) Risk Externalities, that arise when the uncertainty in the availability of surface water is considered, which increases the optimal use value of groundwater for all firms, but firms fail to internalize this value. Gardner et al. (1990) also considers "technological externalities", that arise when the presence of a new technology adopted by of one group of users affects the extraction costs of those that did not adopted the technology (please see the following subsection)[2].

Another strand of research has focused on the analysis of investment decisions. Theory suggests that, when decisions are taken individually, each agent will decide the optimal moment of investment, especially when investment is irreversible and is made only once in lifetime. Some researchers have analyzed investment in efficient irrigation technologies under uncertainty, and focus on the analysis of the option value of investment (Barham et al., 1998; Carey and Zilberman, 2002). However, when there is interaction between users (e.g. aquifer problem), strategic behavior might arise due to technological externalities (Gardner et al., 1990). For instance, Agaarwal and Narayan (2004) develop a dynamic two-stage game in which agents choose the level of initial investment for the capacity of a well and subsequent extraction. They show that, due to strategic behavior in investment, agents invest

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[2] For this study, we will not consider risk and congestion externalites, given that none of the parameters considered in the experiments are stochastic, nor spatial or network effects are introduced.

in excess capacity, allowing the overexploitation of the aquifer. Barham et al. (1998) also analyze the relationship between sunk costs and strategic behavior but in a context of a non-renewable resource.

In the problem presented in this study, the adoption of efficient irrigation technologies should help to increase the water table over time, reducing costs of extraction. Thus, some farmers could have the incentive to delay adoption given that they are already being benefited by those farmers who already adopted. The problem presented in this study is similar to the one presented in Moretto (2000) and Dosi and Moretto (2010), without considering uncertainty in returns. Moretto (2000) develops a theory where irreversibility effects and war of attrition effects are compounded in the decision of producers to adopt a new technology. They find switching trigger values at which producers will switch from one technology to another. Finally, Dosi and Moretto (2010) analyze the implementation of auctioning investment grants for 'green' technology adoption and find them to be a cost-effective way of accelerating pollution abatement. It is important to mention that in Moretto (2000) and Dosi and Moretto (2010), the cost of adoption of new technology changes with the rate of adoption of other agents.

4 The Groundwater Management Game

In this section we briefly present the theoretical model that has been used for the experimental design. We closely follow the model presented in Provencher and Burt (1993), and the methods used in this study are very similar to those used by Giordana (2008). In order to facilitate the presentation of the model, we will first show the individual model of groundwater management with no investment and analyze the solutions for three different types of behavior: Myopic, Rational and Fully Coordinated. Then, we will present the individual model for both groundwater consumption and optimal investment.

The functional forms that we have chose for the experimental design follow Wang and Segarra (2011). These authors consider a profit function that is linear on the demand of water. They argue that crop water-related yields tend to increase linearly with the amount of water applied until they reach a plateau, due to the natural capacity of plants to absorb the water. We also adapted the model presented in Provencher and Burt (1993) to consider dept-to-water instead of the stock of water that remains in the aquifer. We believe that farmers are more closely related to the concept of water table and depth rather than the stock of water, since it is unknown.

4.1 Basic game (Baseline)

There are N farmers that use groundwater for irrigation. They pump water from a bathtub-type aquifer through water wells, and they do not have access to surface water. In our model, we will only consider the costs related to changes in the water table, not those related to well digging [3].

Farmer benefits from agriculture are denoted by:

$$B_{it} = \alpha w_{it} h - w_{it}\frac{\beta}{S_t} - k = w_{it}\left(\alpha h - \frac{\beta}{S_t}\right) - k$$

Where w_{it} is the amount of water pumped by farmer i in period t, α is the marginal value of

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[3] Although we believe that these decisions and costs are extremely important, we tried to simplify the model in order to make make the application with farmers easier.

production of irrigated land, $\frac{\beta}{S_t}$ is the marginal cost of water pumped from the well, S_t is the stock of water in the aquifer in period t, and k is the fixed cost of production. As commonly assumed in the groundwater literature, only production costs related to groundwater are variable. We assume that farmers already made all the decisions regarding the use of other inputs, and their cost is considered in the fixed cost k. Note that the marginal cost of water pumped is inversely related to the stock of water in the aquifer. If the stock of water increases, then the water table increases and farmers have to pump water from a higher point in the well, which requires less electricity and reduces pumping costs. Finally, there is no heterogeneity between farmers, so we will consider the symmetric case.

We believe that the concept of stock of water was less understood by farmers than depth of water extraction. Thus, we changed the cost function using the following transformation. We considered the aquifer as a cylinder with a radius of $\bar{R}$ and height of $\bar{D}$. Then, the maximum capacity of the aquifer is denoted by the $\bar{D} \times \pi\bar{R}^2$. However, the stock of water of the aquifer will change over time due to exploitation. Then, the stock can be observed using the difference between the maximum depth of the aquifer, $\bar{D}$, and the depth at which water is pumped, d_t. The stock of water at time t can be represented by: $S_t = \left(\bar{D} - d_t\right) \times \pi\bar{R}^2$. With this identity, we can transform our current-period profit function to:

$$B_{it} = w_{it}\left(\alpha h - \frac{\beta}{\left(\bar{D} - d_t\right) \times \pi\bar{R}^2}\right) - k \tag{1}$$

The equation of motion of the water table is represented by the following equation:

$$d_{t+1} = d_t + \frac{W_t}{\pi\bar{R}^2} - \frac{f}{\pi\bar{R}^2}$$

Where W_t is the demand of water of the N farms, $W_t = \sum_{i=1}^{N} w_{it}$, and f is the natural recharge of the aquifer in period t.

We also need a boundary constraint for the total water used, since no water beyond $\bar{D}$ can be pumped. This is represented by:

$$d_t + \frac{W_t}{\pi\bar{R}^2} \leq \bar{D}$$

Farmers will make decisions towards water demand depending on the behavior assumed. We will analyze the cases when all farmers are myopic, rational and fully cooperative.

Given the functional form used in this model, a myopic water user will pump the maximum possible amount of water every period, as long as profits are positive, since myopic water users do not internalize the future consequences of their water consumption today. Moreover, there are no contemporaneous externalities from other water users in our model. Then, the demand of a myopic user is represented by:

$$w^m = \begin{cases} \bar{w} & \text{if} \quad d_t \leq \bar{D} - \frac{\beta}{\pi R^2 \alpha h} \\ 0 & \text{otherwise} \end{cases}$$

Where $\bar{w}$ is the maximum amount of water that can be pumped.

On the other hand, a rational water user will consider the future value of water in their decisions. She will also consider the behavior of other groundwater users, since their decisions will affect the stock of water in the future, and therefore the welfare of all users. Thus, the problem that the rational water user solves is:

$$
\begin{aligned}
& V_{i1} = \max_{\{w_{it}\}_{t=1}^{T}} \left[\sum_{t=1}^{T} \delta^{t-1} B_{it} \right] \\
\text{s.t} \quad & \\
& d_{t+1} = d_t + \frac{1}{\pi \bar{R}^2} \left[\sum_{j=1}^{N} w_{jt} + f \right] \\
& d_t + \frac{1}{\pi \bar{R}^2} \sum_{j=1}^{N} w_{jt} \leq \bar{D} \\
& d_1 \quad \text{given}
\end{aligned}
$$

Where δ is the discount rate. The experiments developed in this study do not consider heterogenous agents, so we can assume, for the theoretical model, that all users are the same and that agent i can identify with certainty the other users' choices, and therefore user i maximizes its current value function given the other users' best response[4]. Recalling the optimality principle, we can write the Bellman equation for agent i and period t as:

$$
\begin{aligned}
& V_{it}(d_t) = \max_{w_{it}} \left[w_{it} \left(\alpha h - \frac{\beta}{\left(\bar{D} - d_t \right) \times \pi \bar{R}^2} \right) - k + \delta V_{i,t+1}(d_{t+1}) \right] \\
\text{s.t.} \quad & \\
& d_{t+1} = d_t + \frac{1}{\pi \bar{R}^2} \left[w_{it} + (N-1)\,\phi(d_t) + f \right] \\
& d_t + \frac{1}{\pi \bar{R}^2} \left[w_{it} + (N-1)\,\phi(d_t) \right] \leq \bar{D} \\
& d_1 \quad \text{given}
\end{aligned}
$$

Where $\phi(d)$ is the best decision taken by the other $N-1$ firms and, as before, $h < 1$. The solution of the problem will depend of the type of strategies that agents choose. *Open-loop* strategies only depend on time and not on the current state (d_t), given that agents take the initial information and define an optimal path of extraction, whereas *feedback* or *close-loop* strategies will depend on both time and current state. Negri (1989) and other authors argue that *open-loop* strategies are not consistent, given that agents can correct their paths over time. Provencher and Burt (1993) show that the solution of this problem involves two different types of externalities: strategic and stock. Strategic externalities arise when *feedback* strategies are followed. These externalities negatively affect the efficient allocation of the resource and could encourage the depletion of the resource.

A controlled solution of the problem differs from the individual problem in that externalities are fully internalized. Assuming homogeneity of agents, the symmetric problem can be represented as:

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[4] Nevertheless, for empirical purposes, conjectures about other users' decisions should vary between individuals, depending on observable and unobservable variables.

$$
\begin{aligned}
& N\tilde{V}_{it}\left(d_t\right)=\max_{\tilde{w}_{it}} N\left[\tilde{w}_{it}\left(\alpha h-\frac{\beta}{\left(\bar{D}-d_t\right)\times\pi\bar{R}^2}\right)-k+\delta\tilde{V}_{i,t+1}\left(d_{t+1}\right)\right] \\
\text{s.t.} & \\
& d_{t+1}=d_t+\frac{1}{\pi\bar{R}^2}\left[\tilde{w}_{it}+(N-1)\,\tilde{\phi}\left(d_t\right)+f\right] \\
& d_t+\frac{1}{\pi\bar{R}^2}\left[\tilde{w}_{it}+(N-1)\,\tilde{\phi}\left(d_t\right)\right]\leq\bar{D} \\
& d_1 \quad \text{given}
\end{aligned}
$$

Where $\sim$ denotes values at the social optimum. If concavity of V and $\tilde{V}$ is guaranteed, Provencher and Burt (1993) show that the individual demand of water is greater than the socially optimal demand and it leads to a lower steady-state equilibrium. With a proper parametrization, it is possible to solve both problems numerically (see below).

4.2 Investment

Now, we will consider the situation where farmers are allowed to invest in new irrigation technology. This new technology has a level of irrigation efficiency equal to 1. Thus, less water is required to achieve the same production levels as with the old technology. This technology is adopted only one time in lifetime. However, the cost of adopting the new technology is I. Also, with the new technology, it is necessary to spend every period an additional maintenance cost of m[5]. The period benefits with the default technology are denoted as B^0 and are represented by equation (1), whereas benefits with the more efficient technology, without considering the investment cost, can be represented by:

$$
B^1_{it}=w_{it}\left(\alpha-\frac{\beta}{\left(\bar{D}-d_t\right)\times\pi\bar{R}^2}\right)-k-m \tag{2}
$$

With the two technologies available, the farmer not only has to decide the optimal path of pumped water, but also the optimal moment at which he/she switches to the efficient technology. These two situations can be combined as follows. In any period, say τ, the farmer will choose whether to invest or not in the technology, in order to maximize his/her present value of the utility, $V_{i\tau}$, taking into account the equation of motion of the stock of water in the aquifer and the boundaries of w_{it}:

$$
\begin{aligned}
& V_{i\tau}=\max\left\{V^0_{i\tau},V^1_{i\tau}-I\right\} \\
\text{s.t.} & \\
& d_{\tau+1}=d_\tau+\frac{1}{\pi\bar{R}^2}\left[w_{i\tau}+(N-1)\,\phi\left(d_\tau\right)+f\right] \\
& d_\tau+\frac{1}{\pi\bar{R}^2}\left[w_{i\tau}+(N-1)\,\phi\left(d_\tau\right)\right]\leq\bar{D} \\
& d_1 \quad \text{given}
\end{aligned}
$$

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[5] This additional cost can be interpreted as the cost incurred in hose and filter replacement for dip irrigation technology.

Where

$$V_{i\tau}^{0} = B_{i\tau}^{0} + \delta V_{i,\tau+1}$$

and

$$V_{i\tau}^{1} = \sum_{t=\tau}^{T} \delta^{t-1} B_{it}^{1}$$

Again, $\phi(\cdot)$ denotes the best strategy of the other users. Note that the present value of the utility of not investing in τ, $V_{i\tau}^{0}$, considers the possibility of investing in the new technology in the next period $\tau+1$, whereas investment in τ is considered irreversible.

This problem can be solved using the two-step method proposed by Agaarwal and Narayan (2004). The first stage involves the investment decision whereas the second stage solves the optimal extraction path $\{w_{it}\}_{t=1}^{T}$. We can search for the optimal extraction path conditional on the investment timing decision $\hat{t}$, $\{w_{it}\left(\hat{t}\right)\}_{t=1}^{T}, \hat{t} = \{1, 2, ..., T\}$. Each $\hat{t}$ will yield a lifetime utility $\hat{V}\left(\hat{t}\right)_{i1}$. Then, the optimal investment time, t^{*}, can be represented as:

$$t^{*} = \text{argmax}\{\hat{V}\left(\hat{t}\right)_{i1}\}, \quad \forall\hat{t} = \{1, 2, \ldots, T\} \tag{3}$$

Myopic agents do not care about the future, so they will not invest in the new technology. On the other hand, rational/strategic agents might be willing to invest in the new technology if every user is willing to invest. However, there is the possibility of *free-riding*: If agent i believes that the other users will invest, he/she will benefit from their water savings. Therefore, agent i does not have incentives to invest. If this is the case, then all the agents will have the same strategy. Thus, the Nash equilibrium will be the resulting equilibrium. So two equilibria might arise, one in which everyone invests in the first period, and the other, in which no one invests.

4.3 Communication

Non-cooperative game theory does not predict good results from communication and agreements: everyone deviates from the agreement and play Nash. However, it is possible to analyze the effects of agreements using the approach developed by Dixon (1989). He analyzes whether groundwater users apply trigger strategies when any of their peers deviate from an agreement already made. However, the analysis of the agreement itself is not matter of non-cooperative game theory.

In our study, we will consider fixed agreements as a way to achieve a second best. Although there is a specific path with which the social optimum can be achieved, in our case, some specific fixed arrangements will yield better results than those achieved by both myopic and rational/strategic agents. Then, it would be better to stay with the arranged fixed amount. Nevertheless, deviations from the arrangement might appear. It might be that changes in stock might trigger some kind of behavior that leads to deviations of the agreements.Also, some agreements might work better than others, even if they yield to better results than the Nash and myopic.

4.4 Parametrization, myopic, rational and optimal behavior

The total number of water users for each well was $N = 4$. Also, in order to facilitate the decision-making process of participants, we discretized the number of hours of water that they can use. Then, for this experiment, $w_{it} = \{0, 1, \ldots, 10\}$. Also, we allow the efficiency level of the irrigation technology to be $h = 0.5$ with the less efficient technology, and $h = 1$ with the highly-efficient one. In that sense, it will be required 10 units of water to irrigate all the land with the less efficient technology, but only 5 units with the more efficient one (see "Framing" subsection).

The life span of participants will be of 5 production years. After year 5, they retire from farming and receive their reward (V_{i1}). Thus, it is not important for them if there is water left in the aquifer[6]. The initial depth of extraction is set to $d_0 = 170$ meters. This depth is similar to the average depth of extraction in the region, so participants accepted this level easily.

All the parameters that were used in the experiments are presented in Table 2. Also, tables 4, 5 and 6 present the revenues with the less-efficient technology, highly-efficient technology and the costs of extraction. Note that revenues with the highly-efficient technology increase with the number of units used up to five units. After five units, revenues do not change. This is because farmers posses a fixed agricultural area and, with the parameters used, all the area that they hold is irrigated with 5 units (see "Framing" subsection). Also, note that the cost changes with each level of the depth of extraction and the number of water units required.

It is important to mention that the parameters were set in a way that it is not profitable to use water if there is less water in the aquifer than the necessary to supply the maximum amount that users can require. Thus, beyond $d_t = 210$, it is more profitable to request zero hours of water and just cover the fixed cost of production. With these parameters, we calculated the myopic, rational/strategic and fully coordinated paths for the basic game.

The trajectories of units of water used, costs and well depth for each type of equilibrium are presented in figures 2, 3 and 4. We also calculated the total benefits from possible "fixed arrangements" in the number of water units. This exercise could represent the situation in which there is an agreement between users. The results are presented in figure 5. The equilibrium total benefits without including the initial capital[7] for myopic agents is 76.25; 108.75 for rational/strategic agents; and 165.82 for fully coordinated agents. Also, we can see that the value function is not linear for different fixed arrangements. Moreover, with arrangements of five, six and seven units for each period, it is possible to achieve net benefits higher than the Nash equilibrium. This situation suggests that, in this experiment, it is possible to be better-off than the Nash equilibrium if water users comply with the agreement of pumping six units in each period.

In order to solve the model for the "Interaction-investment" situation, we first solve the same problem in the case when only the highly-efficient technology is available. In this case, we set the parameters in a way that it is possible to achieve the same social optimum with the two technologies. This was done in order to avoid the introduction of a bias from the parameters chosen.

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[6] Although we believe that it is important to give a value to that water, it would required the valuation of the ecological benefits of that stock, and this valuation goes beyond the scope of this paper.

[7] See next section for details

5 Experimental design

5.1 Research area and recruitment of participants

Farmers from the State of Aguascalientes were recruited for the experiments, and the information of 256 farmers will be used in this study[8]. Farmers were contacted in several ways. The most efficient way to recruit farmers was through delegates of the sections of the Irrigation Distric 001 and engineers that worked on the region. We also contacted farmers through professors of the Univerisdad de Aguascalientes[9]. 52 farmers participated in 4 sessions between April and May of 2012, whereas in the period between September and October of 2012, we developed 21 sessions with 204 farmers. The sessions were developed in rooms provided by the *Comisario Ejidal* or by the Irrigation District. Only in three occasions, we developed the sessions on the field, where the water well is located.

Farmers use water for irrigation purposes[10], and we allow the source of water to be a water well or a dam. In many cases (37.89 percent), farmers had the two sources. As we will show in the next section, the game that will be played is based on a situation in which farmers pump water from a well. However, we allowed the participation of farmers that do not have a well because these farmers are potential users of a well (given the declining rain in the region, farmers are getting more permissions for well digging), and there might be differences in the behavior between these two groups. Also, all the farmers were very familiar with the context. The distribution of recruited farmers in Aguascalientes is presented in Table 1.

5.2 Framing

We framed the experiment in the following way. Each participant holds $\bar{H}$ has. of land devoted to agriculture. This land could be irrigated or not, depending on water users decisions. The amount of land is fixed over time throughout the game and it is the same for all participants. Participants are water users that extract water from a well. There are N water users in each well. Water users are homogenous but they do not know for sure what the other users do (see below for a description of the session).

Each period will represent one year of production. In that sense, water users will decide the amount of water they will use for the entire production year. Farmers' decisions on the amount of water will be made in terms of hours of water/day pumped from the well, w_{it}. Each irrigated hectare requires $2h$ hours of water/day from the well, where h is the level of efficiency of the technology that the farmer has in place ($0 < h \leq 1$). For instance, in order to produce on the $\bar{H}$ has., farmers have to use $w_{it} = \frac{\bar{H}}{2h}$ hours of water a day. However, they do not have to work in the whole $\bar{H}$ has. They can decide to irrigate $H < \bar{H}$ has. In that sense, we can say that the total irrigated land for the period will depend on both the water requirements that they scheduled and the level of efficiency, $w_{it}2h$.

As mentioned above, changes in the depth of the water well will depend on the amount of water that farmers use. For the sake of consistency of information, we told participants that one hour of

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[8] We gathered information of 299 farmers, however the information of the first three sessions, which included 32 farmers, was used as a pilot due to several changes in the experimental design. In addition, the information of one session with 12 farmers is not included because they did not finish the session

[9] We also attempted to contact farmers in the *Feria Nacional Agropecuaria de San Marcos*, one of the most important agricultural fairs in Mexico. The *Universidad de Aguascalientes* allowed us to get a kiosk in which we could developed the session. However, this strategy did not result.

[10] Only two farmers had rain-fed land

water pumped from the well will contribute to the depth of the well in one meter. Finally, each farmer has an initial capital of C.

5.3 Treatments and sessions

Treatments

The experimental design consists of two treatments with two levels (on and off). The treatments that will be considered are:

Investment in technology (IN): In this treatment, farmers will be allowed to invest in irrigation technology. Farmers are free to choose the time in which the investment is done. The cost of investment is I.

Internal agreement (AG): Before the players make any decision regarding water consumption, they agree on a fixed amount of water that they should pump in each period. After the participants make their agreements, they individually and anonymously decide whether they comply with or deviate from the agreement.

We excluded the experimental condition in which the two treatments are activated[11]. We called the "Counterfactual" treatment (CF) to those sessions when the two treatments are deactivated. As noted in Table 3, 21 groups participated of the CF and IN sessions, and 22 groups participated of the AG treatment.

Initially, treatments were assigned randomly. We made a raffle to decided which treatment will be applied. After some sessions were already developed, we considered the number of sessions already assigned in each treatment to assign the treatment for the next session. For instance, if there was a deficit of AG sessions, we decided to apply that treatment to the following session. We did not took into account any characteristics of the population, location or the number of potential attendants to assign the treatments to sessions.

Sessions

Games were played by groups of 4 participants. Each group represented a water well and the four members of the group had to pump water from the same well. We called the wells by colors: yellow, blue, orange, green and red. The number of wells that participated in the session varied depending upon the number of attendants. We did not run sessions with more than 20 participants to guarantee tractability. Each participant received a card of the color of the group membership. Colors were assigned randomly. We made sure that members of each well did not sit together in order to avoid collusion. Therefore, when possible, we arranged individual tables in the session, and members of the same group sat in each table separately and in different parts of the room. However, the most common setup was one in which we arranged four big tables and one member of each group sat in each table. Depending on the number of groups, one to five people could sat in the same table. Also, each well played a game independently. In other words, wells did not compete for water and there was no relationship between them. Thus, although members of different wells sat together, they did not take actions upon the same information. However, it might be possible to find some correlation between groups. It is possible to control for that in the analysis.

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[11] To fully estimate the effects of the treatments, it is necessary to run sessions with a combination of the IN and AG treatments (Collins et al., 2009). We could not run that type of session and we believe that would have been more complicated for the farmers.

All the participants played for 10 rounds. The first 5 rounds (Stage 1) corresponded to the baseline situation, in which no investment nor agrement treatments were in place. After the first 5 periods, the following 5 rounds (Stage 2) corresponded to a specific treatment. We applied 3 types of sessions in the experiments. The type of session (CF,IN,AG) was informed after the end of the first stage.

Before the participants make their investment and consumption decisions for the first round, the initial well depth is informed to all the members of the group. This information is public along the game and is the same for all the water wells.

Each participant has a revenue table for the case of the less-efficient technology and, only for the case when the IN treatment is in place, participants have the revenues for the two technologies, as shown in tables 4 and 5. They also have the cost table presented in Table 6. Costs do not change between treatments. With this information, participants can decide how many hours they pump. They write down all their decisions for the first round in their account sheet. Once all participants made their decisions, calculated their income, cost and benefits for the first period (here the facilitator and assistants helped with these tasks), the facilitator proceeds to count how many hours were used by each participant for each well. This exercise is done in a way that the other members of the well do not notice who are their group partners. Then, we calculate the change in the depth of extraction of each well and make this information public to proceed with the second period. This exercise is repeated four more rounds and in each time we update the depth of the well.

For the second stage, we start again from the initial well depth (170 m.). If the type of session is "IN", participants will be able to invest in a highly-efficient technology. This is communicated to all participants before the round starts. However, this technology costs an amount of I and is a one-time investment. Thus, every period, they have to decide whether to invest or not in the technology and the amount of water to pump. Once the technology is adopted, they will only calculate their benefits using the table of the highly-efficient technology, shown in Table 5.

If the type of session is "AG", the members of each well meet for 10 minutes before the game starts and discuss a fixed amount of water that they will request for each period throughout the game. This agreement will be written in their accounting sheet. After the meeting, we proceed to play a game similar to the baseline. Participants can anonymously decide whether to comply with the agreement or deviate.

5.4 Rewards

As mentioned above, each farmer receives an initial endowment C. Then, the payoffs at the end of each stage will be composed by C plus the total net benefits from production that the farmer earned through the five periods minus I if the farmer adopted the technology in the second stage of the "IN" sessions . At the end of the second stage, each farmer will toss a coin marked with "1" and "2". If the coin shows "1", he will receive the amount earned in stage 1, otherwise, he receives the amount earned in stage 2. Participants will get a fixed reward of 200 MX Pesos (US$16) for their attendance. The total earnings that participants got are between 200 MX Pesos and 441 MX Pesos[12].

5.5 Survey

We conducted a survey at the beginning of each session. The purpose of the survey is to complement the data gathered in the experiments and analyze whether any "real life" variables determine the

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[12] Some participants earned total benefits lower than 200 MX Pesos, however, we set the minimum amount to 200.

behavior and attitude of water users in Aguascalientes in the experiment. The survey consisted on five sections and we asked about farmers' land tenure, major crops and livestock, farmers' experience and demographics, water access and use, and irrigation technology available on the field. The facilitator read each question of the survey and each participant answered individually with the help of assistants. Participants took between 20 and 30 minutes to fill the survey. A summary of the variables collected in the survey is presented in the next section.

Tables 8 and 9 present means and proportions of the variables gathered in the survey for each treatment group, "Counterfactual", "Investment" and "Agreement". We can see that there are some important differences between the mean values and proportions of some variables of each of the treatment groups, even though we assigned the treatments randomly. For instance, water wells as the main source of water has a higher presence in the CF group than the other two groups. Also, we can see that the AG group shows a higher proportion of farmers with drip irrigation, as well as a higher proportion of farmers that work only on farm. Although these differences may not affect the final outcomes, it is necessary to take them into account in the analysis.

6 Analysis of data and results

We conducted 25 sessions with a total of 256 farmers in two periods: between April 30 and May 13, and between September 9 and October 10 of 2012. The 256 observations comprise a total of 2,560 periods played. The summary of sessions is presented in Table 3.

6.1 Experiment Outcomes

The main outcomes of the experiments are the number of pumping hours, revenues, costs and benefits in each period, and the total net benefit, total hours pumped and final well depth. In Table 10 we can see the mean values for the last three variables. The mean differences tests are performed between stages for each treatment (CF, IN and AG). As we can see, there are significant differences only for the outcomes of the IN treatment and there are no significant differences between stages for the other two groups (CF and AG). We also ran difference tests between the treatments within each stage. These results are presented in Table 11. We can see that there are some differences in the outcomes in Stage 1, between the CF and IN treatments. This suggests that, even though the treatments were assigned randomly, there are some unobservable differences in the sessions and attendants that has to be considered in the analysis. On the other hand, in Stage 2, almost all the outcomes from the IN sessions are significantly different from the CF sessions, as expected, whereas the mean differences between the outcomes from the AG and CF sessions are not significantly different to zero. This might be because the dispersion of the resulting total benefits increases in Stage 2, as we present below.

With respect to the period variables (hours of pumping, revenue, cost and benefit), Table 12 shows the mean values of the period outcomes of the experiment for each of the treatments in each stage and period. With the exception of revenue in Period 1, all the outcomes of the IN treatment in Stage 2 are significantly different to the outcomes of CF, on average, whereas none of the outcomes of AG in Stage 2 are significantly different on average from the outcomes of CF. Although this could be a sign that the treatment does not have any effect on the behavior of participants and therefore on the resulting outcomes, it is necessary to make a deeper analysis of the results, given that the behavior of the participants also changed between stages 1 and 2 for the CF treatment. Moreover, looking at Table 12, it is clear that there exist some initial differences between the outcomes of the

CF and the other two treatments in Stage 1, where all the participants played the baseline. These results are also presented graphically in figures 6 to 10.

It is worth to notice the important increase in the costs of pumping for the AG group in the last period of Stage 2. There are some observations that show extreme values in costs, which yield to very negative benefits. This seems irrational since the game is designed in a way that, when the well depth is to high, it is more profitable to pump zero hours of water and get low losses. However, as we will discuss below, many participants where reluctant to use zero hours of water because they felt that they had to get "something to survive", as in reality. Thus, even though the costs of pumping were really high, they still decided to pump water.

Another interesting observation is the change in the distribution of pumping hours over the game. Figure 11a shows kernel density estimations of the distribution of pumping hours for the three treatment groups in Stage 1, whereas Figure 11b presents kernel density estimations of the distribution of pumping hours for the CF and AG groups in Stage 2. The IN group is not presented in Figure 11b given that it basically collapses to the value of 5. In period 1 of Stage 1, the distributions of the three groups are bimodal, one mode centered in 5 hours and the other mode centered around 9. Then, the three distributions start to become flatter, which means that the dispersion of the decisions is increasing. For the case of the IN and AG groups, it seems that the participants are choosing lower values, since the left side of the distribution becomes broader. However, for the CF group, although some lower values appear, the biggest changes are observed in the higher values, around 7 and 8. On the other hand, when we look at the values for the CF and AG groups in Stage 2 in Figure 11b, we see that the CF group starts with high values, with a mode between 8 and 10, and the AG group starts with a mode around 6. Then again, the two distributions start to become flatter, but in this case, the participants of the CF group start to choose lower values, whereas those from the AG group choose the higher ones. This behavior observed in the AG group could reflect the strategic behavior of participants, who try to take advantage of the presence of the agreement and defect. Finally, it is worth to mention that the skewness towards higher values is sustained until period three. From period four, the participants start to choose lower values, which makes the distributions to flat faster.

Figure 12 shows the average total net benefit and the theoretical equilibrium values for each treatment and stage. We can see that the average total net benefit reaches the theoretical Nash value for the case of the CF group in Stage 1 (309.77 vs. 308.75) and their difference is not significantly different from zero. On the other hand, the mean total benefits of the IN and AG groups are much lower than the Nash in Stage 1, with their differences significantly different from zero. In Stage 2, again the the total net benefit of the CF group is not significantly different to the Nash equilibrium, whereas the benefits for the IN and AG are significantly lower to their correspondence theoretical values (Social and Nash-IN and Agreement, respectively). In the case of the IN group, the mean total values are much higher than its counterpart in Stage 1, but still it does not reaches the theoretical optimal value. On the other hand, the AG group does not even reaches the Nash equilibrium, even though the theoretical value of the agreement yields.

With respect to the final well depth, Figure 13 shows the observed and theoretical values for each treatment and stage. We can see that the average final well depth for the CF group in Stage 1 is slightly higher than the theoretical social value (198 vs. 200.57), with no statistical differences, whereas the final well depth for the other two groups is significantly higher. For the case of Stage 2, all the observed outcomes of the three treatments are significantly higher than their theoretical correspondence.

It is also interesting to analyze the distribution of these two variables. Figure 14 shows the kernel density estimations of the final total benefit for both stages 1 and 2. For Stage 1, the distributions of the three groups are very similar, unimodal and centered around 300. However, in Stage 2, although the distribution of the CF group is still centered in 300, the dispersion increases, whereas the distribution of the IN and AG groups skewed towards higher values (more in the IN group than in the AG group)[13]. With respect to the distribution of the final well depth presented in Figure 15, we can observe that, as expected, the distribution of IN groups moves towards lower values, since the new technology reduces significantly the amount of water used. On the other hand, the distribution of the CF group shifts to the right-side of the range and reduces its dispersion in Stage 2, whereas the one for the AG groups also shifts towards lower values but its dispersion increases.

6.2 Statistical Analysis

6.2.1 Treatment effects

We are mostly interested in the analysis of the impact of each treatment in three end-of-stage variables: individual total hours pumped, individual total benefits and final well depth. As mentioned before, there are some intrinsic differences between the treated groups, even in the first stage, where no treatment is imposed. If these differences are not taken into account in the analysis, any estimation of the impact of the treatment will be biased. In order to obtain reliable impacts of the treatment, we will estimate a Difference-in-difference model (Cameron and Trivedi, 2005).

Consider the outcome y_{is}^{g} observed at the end of the stage without treatment ($s = 1$) and the stage after treatment ($s = 2$) for three different treated groups: "Counterfactual" ($g = 0$), "Investment" ($g = 1$) and "Agreement" ($g = 2$). Recall that for the case of $g = 0$, there is no treatment imposed in both $s = 1$ and $s = 2$. We can estimate the following equation:

$$y_{is}^{g} = \alpha + \delta + \theta^1 D^1 + \theta^2 D^2 + \phi^1 D^1 \times \delta + \phi^2 D^2 \times \delta + \beta X_i + \upsilon_i + \varepsilon_{is} \tag{4}$$

Where α is a constant, δ is a binary variable that takes the value of one if $s = 1$ and zero otherwise, D^1 is a binary variable that takes the value of one if $g = 1$ and zero otherwise, D^2 is a binary variable that takes the value of one if $g = 2$ and zero otherwise, X_i are fixed individual (group) level observable variables, υ_i is a specific individual (group) level random term and ε_{is} is a individual (group) and time level error term.

We are interested in the value ϕ^g for each treatment, $g = 1, 2$. Estimation of this model with OLS will yield inconsistent estimates because of the presence of υ_i. We used a random-effects model to estimate the equation presented above in order to account for specific individual and treated-group effects. We also considered the full model which includes some of the variables gathered through the survey to control for observable characteristics. Preliminary results are presented in Table 13. Equations (1) through (4) are estimated at the individual level, whereas equations (5) and (6) are estimated at the well (group) level.

The coefficients of interest are "IN X Stage2" for the effect of the "IN" treatment, and "AG X Stage2" for the effect of the "AG" treatment. We can see that the two treatments have a significant effect on the reduction of the total pumping hours and final well depth, whereas only the IN treatment has a positive effect on final total benefits. Also, we can see that there are intrinsic differences between total water used in the groups, since the coefficients of "IN" and "AG" are significant in equation

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[13] For the case of the AG group, we omitted three outliers that are not relevant for the analysis of the distributions. The three participants obtained -354, -637 and -701.

(1) and (2). However, for the total benefits, the initial differences between the groups is not clear. The coefficients that denote differences in stage 2 are marginally significant for the equations of total pumping hours but not significant for the other equations. This suggests that any potential learning between the two stages might affect the results in total pumping hours. However, learning will be more important at the analysis of the dynamics of the game.

We also present the full model including contextual and individual (group) variables. Among the contextual variables included we have indexes for different number of participants in the session (four, eight, twelve, sixteen and twenty), as well as the time and the date in which the sessions were developed. Some of the coefficients of these variables are significant. For instance, the coefficient of Time is significant and positive for the estimation of the total pumping hours. This result might suggest that, for various reasons, participants that attended the sessions developed in the afternoon tend to choose more pumping hours over the game. With respect to the individual characteristics, we can see that the age, working time on farm, irrigated area and area with drip irrigation explain part of the differences between the outcomes. It seems that people less involved with the farm tend to save more water in the game, but at the same time they earn lower total benefits in the game.

6.2.2 Theoretical vs. Observed

The theoretical outcomes obtained in the simulations of the model can be considered as benchmarks of the behavior of groundwater users. These benchmarks abstract from reality, and therefore in the experiments, contextual or individual factors will affect the observed outcomes. Thus, it is important to recognize these factors in order to analyze the behavior and attitude of participants towards the context of the game.

One way to analyze how far the observed outcomes are with respect to the theoretical outcomes is through a measure of efficiency. We know that the social optimum is the socially efficient outcome. We can build a measure of efficiency that corresponds to the ratio between the gains in the game (final total benefits minus initial capital) and the total number of hours used. This would give us a measure of "pesos gained per unit of water". Table 14 shows the average, max and min values of the observed values for each stage and treatment group, as well as the theoretical counterpart.

The index is a measure of individual efficiency, however, it does not consider social efficiency. In other words, having a high index does not necessarily mean that a person is "closer" to social efficiency. We can see this if we plot the index with the final well depth, presented in figures 16 and 17. As shown in Figure 16, the socially optimum combination of "individual efficiency" and "social efficiency" (approximated with final well depth) is the combination depicted by the point labeled "Social". This point is far from the distribution of observed points. However, we can see that there are several points with similar individual efficiency levels but low levels of well depth. This could suggest that some participants were individually efficient in their decisions, but they should have used more of the common resource. We can also observe the position of the Nash equilibrium in the plane. It is located on the far right-side of the plot, indicating that the individual efficiency is low and common resource is overused. This low level of individual efficiency is due to the externalities generated by the other common-pool resource users. The "Fixed arrangement" theoretical outcome is also depicted in the scatter plot, and it is closer to the social optimum. Figure 17 presents scatter plots for the efficiency index and final well depth for Stage 2 by treatment group[14]. Again, several observations show very high individual efficiency, but they lie far from the social optimum. Also,

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[14] Three observations with negative values were dropped from Figure 17c.

the observed points of the IN group are arranged towards the left part of the plot. This is because, overall, participants tend to use less water due to the better irrigation technology. However, the dispersion of the points in this plot is higher than in the other two groups.

Any measure of distance between the observed and the theoretical outcomes should consider these two (or more) dimensions. For this study, we calculate the Euclidean distance between each of the theoretical benchmarks, Social and Nash, and each observation point in the Efficiency Index-Final Well Depth plane. The Euclidean distance is calculated as follows:

$$D^i = \sqrt{\left(e^o - e^i\right)^2 + \left(0.1d_5^o - 0.1d_5^i\right)^2}$$

Where D is the distance to the theoretical outcomes, e is the efficiency index, d_5 is the final depth of the well, subscripts $i = \{N, S, A\}$ denote Nash, Social and Agreement, and the subscript o denotes a measure from the observed data.

Then, we regress each of the distances on the variables gathered through the survey in order to analyze the characteristics of the participants that influence the "degree" of optimality. Table 15 shows preliminary results of Seemingly Unrelated Regressions for each stage and each treatment. We used SUR in order to gain efficiency from the simultaneous estimation of the two equations.[15]. We pooled all the observations for Stage 1 since there is no difference in the games. At first glance, we can see that in Stage 1, the coefficients for treated groups (IN and AG) are significantly different from zero, and suggest that participants from these groups lie further from the social optimum and closer to the Nash, in comparison to the CF group. Also, older people, people that started early in life in agriculture, household heads and people that work some time off-farm lie closer to the social optimum, whereas younger people, people that start later in agriculture, less experienced people, non-household heads, people that have land in *ejidos*, and farmers whose only source of water is a water well are closer to the Nash. In the same way, it is possible to find some relationships between the characteristics of farmers and their location in the Efficiency Index-Well Depth plane for each of the treated groups in Stage 2. Equations (3) to (7) of Table 15 show these results.

6.2.3 Individual-level Dynamics

In the previous sections we showed that the treatments applied in the experiments have significant effect on aggregated outcomes of the game, specifically total hours pumped and total benefits. Nevertheless, the behavior of participants during the game and the factors that explain variability in the behavior is a major task of this study. For instance, some participants may be more likely to behave in a forward-looking behavior whereas others may tend to behave myopically. Moreover, from the previous subsection, it is possible to identify some characteristics of the participants that may drive their behavior in the game. There is also the possibility that the development of the game makes participants to switch their strategies after some threshold, which might be possible given the presence of non-linearities in the model. To answer these questions, it is necessary to analyze the dynamics of the game, especially the dynamics of water demand, the decision variable "pumping hours", and identify what factors affect the behavior of participants and whether they switch or not.

According to our theoretical model, an optimum forward-looking behavior fully internalizes the use value of the resource when a decision about the demand for water is made. Then, at the

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[15] However, this is not a system of equations, since none of the dependant variables in on the other equation as regressor

beginning of the game, fully-coordinated agents define the optimum path, which will depend only on time, given that there is no uncertainty in the game. On the other extreme, fully-myopic agent will disregard the use value of water remaining in the aquifer, and will decide according to the current marginal benefits and costs. We can expect that, in reality, agents could behave in the full range between fully-myopic and fully forward-looking. Dixon (1989) and Arcidiacono et al. (2007) mention that heterogeneity in the behavior of users with respect to the weight assigned to the use value of the resource can be identified through the distribution of the discount factor. Then, it is possible from the data of the experiments to estimate a discount factor given the actions taken by the participants and observable variables gathered through the survey. It might be possible to identify some "types" that lie in the range of fully-myopic and forward-looking, based on their characteristics. This section attempts to structurally estimate this parameter and to test what kinds of behavior fit the data better. It is worth to note that the discount factor that we attempt to estimate with this exercise could be understood as a level of consciousness that participants have about the importance of the use value of water saved in the fictional aquifer during the game, rater than a time preference. We do not attempt to estimate a "real life" time preference of participants. To do that we would have to use "real life" data on water pumping.

Another possible strategy is that, given non-linearities in the functional forms, participants might switch their behavior after some thresholds. Figure 18 shows mean values of water pumped for each level of water depth, with a locally kernel-weighted polynomial smoothing function. The polynomial function was estimated with the original data. The data used in Stage 1 corresponds to all the participants, whereas for Stage 2, we only used data from participants of the CF group, since the treatments assigned could have changed participants' behavior. We can see that average pumping values start to decrease around a well depth of 200. According to the theoretical outcomes, a forward-looking behavior would not behave in this manner, since these type of agents would pump lower amounts of water at the beginning in order to get lower extractions costs for the future. On the other extreme, myopic agents will pump the maximum feasible amount except when marginal costs of pumping exceed marginal benefits (which, for the case of this experiment, it happens at a well depth of 211). Therefore, the observed pattern might be a result of a switching behavior. Another example is shown in Figure 19. This figure shows the average water pumped for each level of water depth and period in Stage 1 with the same smoothing polynomial function (shaded dots are the actual data). We can see that the polynomial function shows a non-linear behavior (a quadratic-type behavior), but also that the slope of the function declines in every period, which suggests that participants consider other effects of the declining stock of water in their demand, besides the effect in costs. Moreover, on period five, it seems that participants sharply reduce the the water demand around 200. Figure 19 also shows the pumping decisions of the four members of a randomly-selected well. We can see that participant 16199 consistently reduces its water demand until period four, and in period five its demand increases. At the same time, the demand of water of participant 16200 consistently increases, again until period 4, and in period five it is reduced. The behavior of the other two agents is more erratic.

These differences in individual behavior could be identified if we use a more general decision-rule. For instance, we could recognize that no all agents behave rationally. Then, some agents might be rationally bounded, whereas others might behave according to heuristics. These differences are important since most of the theoretical models related to groundwater management presume that all agents are rational. Houser et al. (2004) develop a methodology in which several "types" of agents can be identified in a dynamic decision problem. They use Bayesian methods to infer about the "types" of decision rules that participants consider to solve the dynamic problem. Although their application is not a dynamic game as in our study, the authors mention that it is possible to consider conjectures of other participants in the "Future functions" in order to adapt the method to a dynamic game. This method could be applied to the data of the experiments in Aguascalientes in order to disentangle the decision rules that the participants considered in the experiments.

6.2.4 Technology adoption

Another outcome from the experiment that is important to consider is the time of technology adoption in the IN sessions. Variations in this variable might suggest the presence of strategic behavior in adoption for some groups of participants.

Table 16 shows the cumulative levels of adoption for each period of Stage 2. We can see that 68 participants (81 percent) adopted the technology in the first period of stage 2, and then increased until 77 participants. In this case, it is not clear whether some participants show a strategic behavior or not, given that the incidence of technology adoption is very high from the beginning.

6.2.5 Agreement

Finally, it is also worth to analyze the time at which individuals deviate from the agreement in the AG sessions. As mentioned above, the participants from the AG sessions were required to meet for ten minutes before Stage 2 starts in order to agree on a fixed individual level of pumping throughout the five periods. We expect that some participants will deviate and others will comply the agreement. Thus, it is important to analyze the factors that determine the agreed number of pumping hours, as well as the characteristics that affect the timing of deviation.

Figure 20 shows a histogram with the agreed values of pumping hours in Stage 2. We can see that 27 percent of the groups (6 groups) chose a value of 5 hours of pumping, whereas another 6 groups chose a value of 7. The next highest value chosen by participants was 10 hours (4 groups). None of the groups chose values below 5 hours. Table 17 shows the cumulative levels of deviation from the agreement along the five periods of Stage 2. It is also presented graphically through the survival function of the data in Figure 21. We can see that in the first period, 20 participants (22.7 percent) deviate from the original agreement. Nevertheless, by the second period, an additional 35.2 percent of the participants defects. Then, the level of defection slows down until period 5, where 79.5 percent of the participants has already defected the agreement.

With this data, it is possible to analyze how does the hazard of deviation of an agreement changes with different variables. For instance, Figure 22 depicts different survival function for different agreements. It seems that those with with a level of agreement equal to five hours of pumping tend to "survive" more than the other agreements, at least until period 4. Also, Figure 23 shows survival functions for each source of water. Apparently, those that have access to water through both water well and dam tend to deviate faster than the farmers in the two other groups. Thus, it is possible that previous results of the game in Stage 1, agreement levels and the characteristics of farmers will affect the survival levels. Difficulties arise when we try to model survival rates with previous outcomes which are endogenous to unobserved characteristics of participants. Fortunately, it is possible to find instruments in the survey that will help to identify the effects of game outcomes on survival rates.

7 Tables

Table 1: Distribution of participant farmers by Municipality

Municipality	Participants
Aguascalientes	8
Asientos	8
Calvillo	12
Cosio	1
El Llano	61
Pabellon de Arteaga	92
Rincon de Romos	37
San Francisco	1
San Jose de Gracia	24
Tepezala	12
Total	**256**

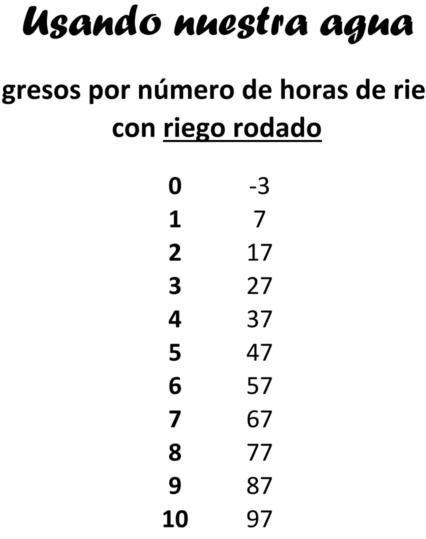
Table 2: Parameters used in experiment

Parameter	Value
α	10
β	390π
h^1	1
h^0	0.5
N	4
H	10
D	250
R	1
C	200
I	150
f	20π
m	9.460879
k	3
d_0	170

Table 3: Summary of sessions

Treatment	**Sessions**	**Groups**	**Participants**	**Periods**
Counterfactual	7	21	84	840
Investment	8	21	84	840
Agreement	10	22	88	880
Total	**25**	**64**	**256**	**2,560**

Table 4: Revenues with less-efficient technology

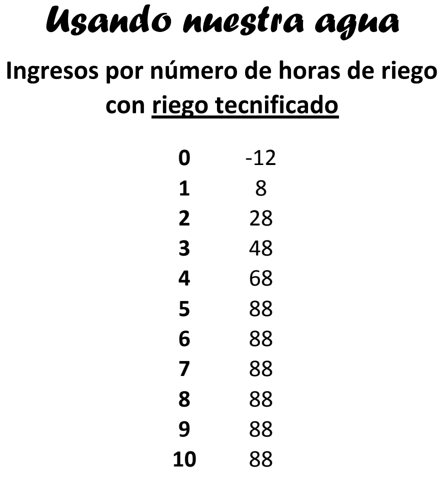


Usando nuestra agua

Ingresos por número de horas de riego
con riego rodado

0	-3
1	7
2	17
3	27
4	37
5	47
6	57
7	67
8	77
9	87
10	97

Table 5: Revenues with highly-efficient technology

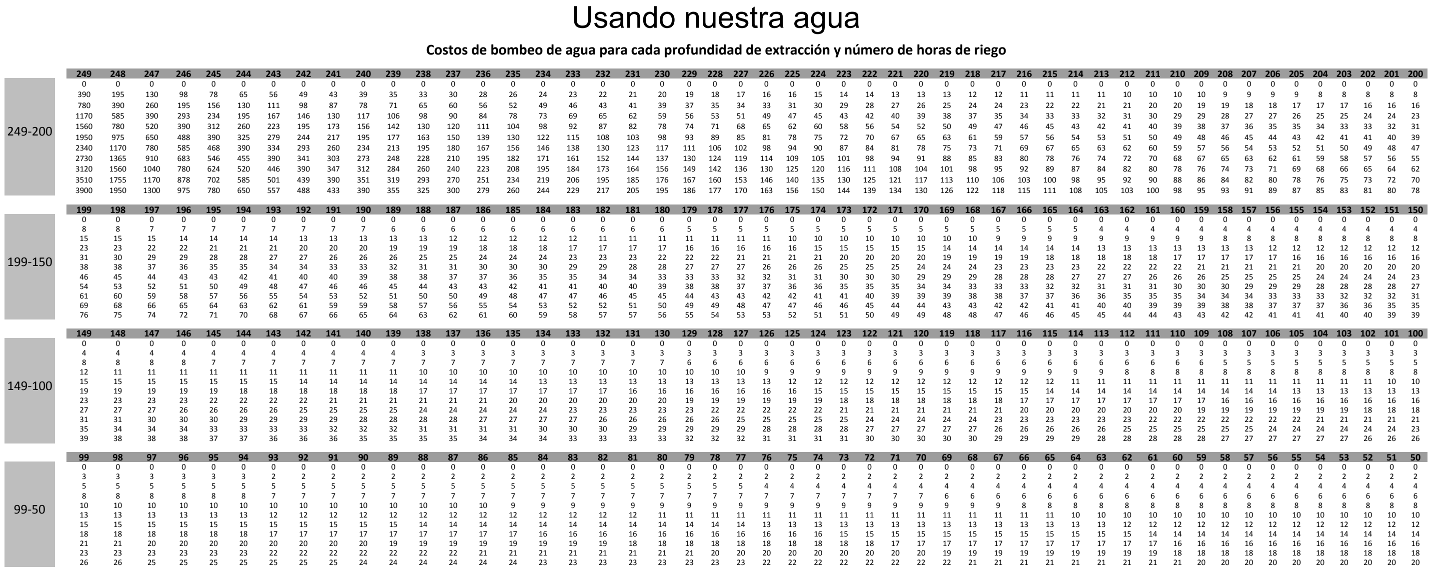


Usando nuestra agua

Ingresos por número de horas de riego
con riego tecnificado

0	-12
1	8
2	28
3	48
4	68
5	88
6	88
7	88
8	88
9	88
10	88

Table 6: Pumping costs



Usando nuestra agua

Costos de bombeo de agua para cada profundidad de extracción y número de horas de riego

	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200
249-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	390	195	130	98	78	65	56	49	43	39	35	33	30	28	26	24	23	22	21	20	19	18	17	16	16	15	14	14	13	13	13	12	12	11	11	11	11	10	10	10	10	9	9	9	9	8	8	8	8	8
	780	390	260	195	156	130	111	98	87	78	71	65	60	56	52	49	46	43	41	39	37	35	34	33	31	30	29	28	27	26	25	24	24	23	22	22	21	21	20	20	19	19	18	18	17	17	17	16	16	16
	1170	585	390	293	234	195	167	146	130	117	106	98	90	84	78	73	69	65	62	59	56	53	51	49	47	45	43	42	40	39	38	37	35	34	33	33	32	31	30	29	29	28	27	27	26	25	25	24	24	23
	1560	780	520	390	312	260	223	195	173	156	142	130	120	111	104	98	92	87	82	78	74	71	68	65	62	60	58	56	54	52	50	49	47	46	45	43	42	41	40	39	38	37	36	35	35	34	33	33	32	31
	1950	975	650	488	390	325	279	244	217	195	177	163	150	139	130	122	115	108	103	98	93	89	85	81	78	75	72	70	67	65	63	61	59	57	56	54	53	51	50	49	48	46	45	44	43	42	41	41	40	39
	2340	1170	780	585	468	390	334	293	260	234	213	195	180	167	156	146	138	130	123	117	111	106	102	98	94	90	87	84	81	78	75	73	71	69	67	65	63	62	60	59	57	56	54	53	52	51	50	49	48	47
	2730	1365	910	683	546	455	390	341	303	273	248	228	210	195	182	171	161	152	144	137	130	124	119	114	109	105	101	98	94	91	88	85	83	80	78	76	74	72	70	68	67	65	63	62	61	59	58	57	56	55
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	3900	1950	1300	975	780	650	557	488	433	390	355	325	300	279	260	244	229	217	205	195	186	177	170	163	156	150	144	139	134	130	126	122	118	115	111	108	105	103	100	98	95	93	91	89	87	85	83	81	80	78

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	21	21	20	20	20	20	20	20	20	20	19	19	19	19	19	19	19	19	18	18	18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	17	17	17	17	16	16	16	16	16	16	16	16	16	16	16
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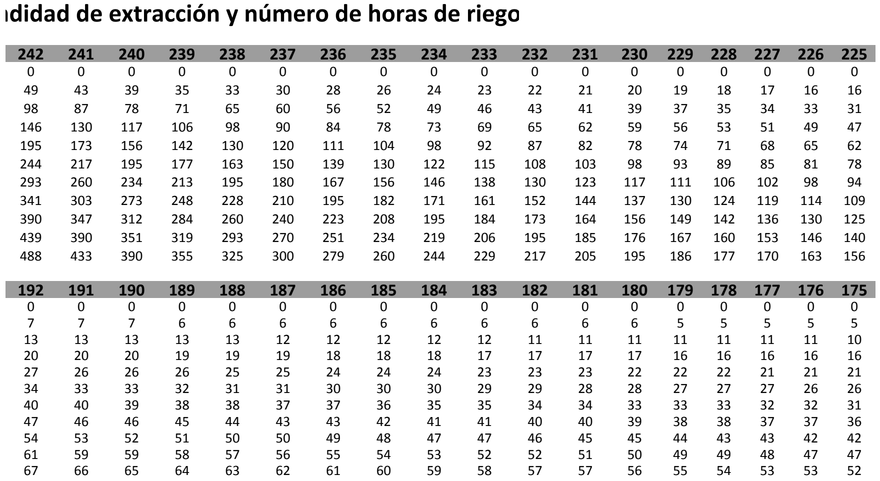
Table 7: Zoom of table of costs



ndidad de extracción y número de horas de riego

242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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98	87	78	71	65	60	56	52	49	46	43	41	39	37	35	34	33	31
146	130	117	106	98	90	84	78	73	69	65	62	59	56	53	51	49	47
195	173	156	142	130	120	111	104	98	92	87	82	78	74	71	68	65	62
244	217	195	177	163	150	139	130	122	115	108	103	98	93	89	85	81	78
293	260	234	213	195	180	167	156	146	138	130	123	117	111	106	102	98	94
341	303	273	248	228	210	195	182	171	161	152	144	137	130	124	119	114	109
390	347	312	284	260	240	223	208	195	184	173	164	156	149	142	136	130	125
439	390	351	319	293	270	251	234	219	206	195	185	176	167	160	153	146	140
488	433	390	355	325	300	279	260	244	229	217	205	195	186	177	170	163	156

192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175
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61	59	59	58	57	56	55	54	53	52	52	51	50	49	49	48	47	47
67	66	65	64	63	62	61	60	59	58	57	57	56	55	54	53	53	52

Table 8: Summary statistics of survey variables (1)

Variable	Counterfactual	Investment	Agreement	Overall
Mean of irrigated land (has.)	7.11	4.23	3.68	4.99
Mean of rain-fed land (has.)	5.11	4.82	3.66	4.52
Farmers with land in *Ejido* (%)	70.24	79.76	94.25	81.57
Owner farmers (%)	86.90	76.19	88.51	83.92
Renter farmers (%)	21.43	25.00	17.24	21.18
Farmers whose major crop is: (%)				
Corn for food	27.71	69.05	41.38	46.06
Corn for Grazing	19.28	20.24	19.54	19.69
Alfalfa	12.05	8.33	22.99	14.57
Beans	9.64	2.38	6.90	6.30
Grapes	9.64	0.00	8.05	5.91
Farmers whose major livestock is: (%)				
Bovine for dairy	53.70	42.11	34.92	43.10
Bovine for beef	22.22	36.84	47.62	36.21
Bovine for double purpose	5.56	7.02	0.00	4.02
Goat	9.26	8.77	7.94	8.62
Swine	3.70	3.51	3.17	3.45
Mean of age (Years)	54.42	46.19	54.98	51.91
Male Farmers (%)	92.86	90.48	95.45	92.97
Marital status (%)				
Single	11.9	26.19	5.75	14.51
Married	79.76	66.67	79.31	75.29
Cohabitant	2.38	3.57	5.75	3.92
Widow	5.95	3.57	9.2	6.27
Education level (%)				
Preschool/none	2.38	1.19	11.49	5.1
Incomplete Primary	34.52	22.62	27.59	28.24
Complet Primary	16.67	21.43	16.09	18.04
Incomplete Secondary	4.76	5.95	8.05	6.27
Complete Secondary	20.24	19.05	17.24	18.82
Incomplete Technician	1.19	5.95	4.6	3.92
Complete Technician	8.33	5.95	2.3	5.49
Incomplete agricultural technician	0	1.19	0	0.39
Complete agricultural technician	2.38	1.19	1.15	1.57
Incomplete upper secondary	1.19	0	0	0.39
Complete upper secondary	0	2.38	6.9	3.14
Incomplete undergraduate	2.38	4.76	1.15	2.75
Complete undergraduate	3.57	7.14	2.3	4.31
Graduate School	2.38	1.19	1.15	1.57

Table 9: Summary statistics of survey variables (2)

Variable	**Counterfactual**	**Investment**	**Agreement**
Working regime (%)			
Only on farm	41.67	38.10	54.02
Mostly on farm	20.24	20.24	6.90
Half-time on farm, half-time off-farm	26.19	30.95	31.03
Mostly off-farm	9.52	8.33	6.90
Only off-farm	0.00	1.19	0.00
Retired	2.38	1.19	1.15
Starting year (year)	1984	1992	1983
Starting land (has.)	7.41	5.86	5.57
Major source of water (%)			
Bordo	2.41	0.00	2.33
Water well	85.54	62.20	54.65
Dam	8.43	35.37	41.86
Other	3.62	2.43	1.16
Water well property			
Private	3.57	0.00	0.00
Shared	82.14	58.33	55.81
Ejidal	4.76	10.71	1.16
No water well	9.52	30.95	43.02
Farmer is part of a water well association	90.79	81.03	95.92
Times of crop watering in first month	2.12	4.26	3.33
Times of crop watering in second month	2.12	3.77	3.32
Times of crop watering in third month	2.01	3.79	3.36
Hours for each watering	16.53	14.97	25.16
Farmers with irrigation technology (%)			
Flood	69.88	74.70	65.12
Sprinkle	7.23	2.41	0.00
Drip	15.66	21.69	34.88
Micro Sprinkle	6.02	0.00	0.00
Other	1.20	1.20	0.00
Area with irrigation technology (has.)			
Flood	3.99	2.64	2.35
Sprinkle	0.56	0.15	0.00
Drip	1.63	1.27	1.24
Micro Sprinkle	0.16	0.00	0.00
Other	0.04	0.04	0.00

Table 10: Average end-of-stage outcomes by type treatment and stage

Differences for each treatment between Stage 1 and Stage 2

Variable	Stage 1			Stage 2		
	Counterfactual	**Investment**	**Agreement**	**Counterfactual**	**Investment**	**Agreement**
Total Benefits	309.77	287.6	295.66	304.63	315.44 *†	274.47
Total hours pumped	32.64	35.57	34.88	34.35	26.36 *†	33.18
Final Well Depth	200.57	212.29	209.55	207.38	175.43 *†	202.73

Calculation of differences at 1% of error between stages for: * means (T-test) and, † distributions (Mann-Whitney test)

Table 11: Average end-of-stage outcomes by type of session and stage

Differences between CF and other treatments within Stage 1 or Stage 2

Variable	Stage 1			Stage 2		
	Counterfactual	**Investment**	**Agreement**	**Counterfactual**	**Investment**	**Agreement**
Total Benefits	309.77	287.6 *†	295.66	304.63	315.44	274.47
Total hours pumped	32.64	35.57	34.88	34.35	26.36 *†	33.18
Final Well Depth	200.57	212.29	209.55	207.38	175.43 *†	202.73

Calculation of differences at 1% of error between CF and treatment for: * means (T-test) and, † distributions (Mann-Whitney test)

Table 12: Average outcomes by type of session, stage and period

Period	Treatment	Stage	Hours of pumping	Revenue	Cost	Benefit	Well Depth
1	Counterfactual	Stage 1	6.99	66.88	34.05	32.83	170.00
		Stage 2	7.24	69.38	35.12	34.26	170.00
	Investment	Stage 1	8.05 *†	77.48 *	39.29 *†	38.19 *†	170.00
		Stage 2	5.61 *†	75.90 †	27.17 *†	48.74 *†	170.00
	Agreement	Stage 1	7.38	70.75	35.86	34.89	170.00
		Stage 2	7.15	68.48	34.39	34.09	170.00
2	Counterfactual	Stage 1	6.51	62.12	35.92	26.20	177.95
		Stage 2	6.95	66.52	38.00	28.52	178.95
	Investment	Stage 1	7.42 *†	71.17 *†	42.92 *†	28.25	182.19 *†
		Stage 2	5.46 *†	78.82 *†	28.24 *†	50.58 *†	172.43 *†
	Agreement	Stage 1	7.26 *†	69.61 *†	39.78	29.83 *†	179.50
		Stage 2	6.85	65.52	37.69	27.83	178.59
3	Counterfactual	Stage 1	6.58	62.83	39.95	22.88	184.00
		Stage 2	6.89	65.93	43.25	22.68	186.76
	Investment	Stage 1	7.18	68.79	50.38 *†	18.40 *†	191.86 *†
		Stage 2	5.25 *†	79.11 *†	27.57 *†	51.54 *†	174.29 *†
	Agreement	Stage 1	7.20	69.05	46.94 *†	22.10	188.55 *†
		Stage 2	6.60	63.02	42.27	20.75	186.00
4	Counterfactual	Stage 1	6.60	62.95	46.04	16.92	190.33
		Stage 2	6.80	64.98	51.21	13.76	194.33
	Investment	Stage 1	6.90	66.05	58.30 *†	7.75 *†	200.57 *†
		Stage 2	5.00 *†	77.08 *†	26.96 *†	50.12 *†	175.29 *†
	Agreement	Stage 1	6.89	65.86	54.94 *†	10.92 *†	197.36 *†
		Stage 2	6.40	60.98	50.10	10.88	192.41
5	Counterfactual	Stage 1	5.96	56.64	45.70	10.94	196.71
		Stage 2	6.46	61.64	56.24	5.40	201.52
	Investment	Stage 1	6.02	57.24	62.24 *†	-5.00 *†	208.19 *†
		Stage 2	5.04 *†	78.99 *†	27.02 *†	51.96 *†	175.29 *†
	Agreement	Stage 1	6.16	58.59	60.67 *†	-2.08 *†	204.91 *†
		Stage 2	6.18	58.82	77.90	-19.08	198.00

Calculation of differences at 5% of error between CF and treatment for: * means (T-test) and, † distributions (Mann-Whitney test)

Table 13: Difference-in-Difference estimation of final outcomes in stages 1 and 2

Variables	(1) Total pumping hours	(2) Total pumping hours - Full	(3) Total Benefits	(4) Total Benefits - Full	(5) Final Well Depth	(6) Final Well Depth - Full
Treatment (Base = CF)						
IN = 1	2.929**	3.949**	-22.18*	-12.23	11.71**	11.78**
AG = 1	2.244*	4.730***	-14.11	-32.24***	8.974*	15.51***
Stage 2	1.702*	1.821*	-5.143	-6.154	6.810	6.810
IN X Stage 2	-10.92***	-11.36***	32.99**	35.44***	-43.67***	-43.67***
AG X Stage 2	-3.407**	-3.858***	-16.05	6.413	-13.63**	-13.63**
Number of participants (Base = 4)						
Participants = 8		-1.760		14.38		-9.922
Participants = 12		0.684		-11.73		-2.555
Participants = 16		-2.848		2.687		-12.03*
Participants = 20		-2.406		39.04		-40.63***
Date		-0.000863		0.0422		0.0164**
Time		0.670***		1.067		0.635
Age		-0.495***		-0.956		
Age^2		0.00369**		0.00737		
Female		1.082		1.665		
Starting Year		7.166		31.91		
Starting Year^2		-0.00182		-0.00803		
Head of household		-1.066		-1.944		
Marital Status (Base = Single)						
Married		0.372		-7.944		
Cohabitant		2.292		21.20		
Widow		1.925		6.058		
Working time (Base = Only on farm)						
Mostly on farm		0.313		1.000		
Half on farm, half off-farm		-2.473**		-4.622		
Mostly off-farm		-4.612**		-17.01*		
Only off-farm		-21.07***		-93.85**		
Retired		-0.741		-4.903		
Education level (Base = Preeschool/None)						
Primary school		-1.092		-8.401		
Secondary school		-1.692		1.052		
Technical school/Preparatory		-1.593		7.655		
Agricultural Technical school		1.237		22.74		
University and Graduate school		-3.671		2.349		
Irrigated hectares		0.813***		3.572***		
Irrigated hecatares^2		-0.0110***		-0.0398**		
Land is *ejido*		0.970		15.59		
Source of water (Base = Dam)						
Only water from well		0.170		6.515		
Both water from well and dam		0.206		1.479		
Primary crop alfalfa		-0.192		-0.642		
Primary crop vine		6.235**		23.07		
Area with drip irrigation		-0.373***		-2.246***		
Municipality (Base = Pabellón de Arteaga)						
Aguascalientes		-0.0240		5.909		
Asientos		-1.080		-57.86***		
Calvillo		-7.971**		27.69		
Cosio		-0.664		19.56		
El Llano		-1.573		-12.40		
Rincón de Romos		-4.127**		0.499		
San Francisco		-3.965		-53.72		
San José de Gracia		-7.981*		-10.97		
Tepezalá		-1.480		1.163		
Constant	32.64***	-6,957	309.8***	-36,554	200.6***	-1,783*
σ_u	5.882***	4.137***	25.95**		9.117**	
σ_e	6.411	6.38	74.32	47.77	14.93	15.02
Observations	512	474	512	474	128	128
Number of caseid	256	237	256	237	64	64

Equations (5) and (6) estimated at the well (group) level

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Likelihood-ratio test performed for significancy of σ_u

Table 14: Individual observed and theoretical pesos gained per unit of water used, by treated group and stage

Group	Statistic	Stage 1					Stage 2				
		Observed	Myopic	Rational	Coordinated	Fixed agreement	Observed	Myopic	Rational	Coordinated	Fixed agreement
Counterfactual	mean	3.40	1.91	2.72	5.18	4.05	3.10	1.91	2.72	5.18	4.05
	min	1.56					-1.15				
	max	4.50					5.16				
Investment	mean	2.56	1.91	2.72	5.18	4.05	4.48	1.91	6.80	6.80	6.80
	min	0.02					-6.80				
	max	4.84					7.24				
Agreement	mean	2.88	1.91	2.72	5.18	4.05	2.69	1.91	2.72	5.18	4.05
	min	0.19					-19.02				
	max	4.90					5.65				
Overall	mean	2.94	1.91	2.72	5.18	4.05	3.41	1.91	4.06	5.71	4.95
	min	0.02					-19.02				
	max	4.90					7.24				

Table 15: Seemingly Unralted Regression for distance to Social and Nash locations in the Efficiency Index-Well Depth plane, by stage and treatment group

Variables	CF, IN and AG - Stage 1		CF - Stage 2		IN - Stage 2	AG - Stage 2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Social	Nash	Social	Nash	Social/Nash	Social	Nash
Treatment (Base = Counterfactual)							
IN	1.237***	-1.250***					
AG	1.010***	-0.940***					
Age	-0.412**	0.748***	0.729*	0.426	1.267	0.0245	-0.829
Age x Starting year	0.000216**	-0.000378***	-0.000364*	-0.000220	-0.000663	-2.27e-05	0.000426
Female	0.259	-0.252	1.076*	-1.429***	-0.253	0.0840	-2.209
Head of Household	-0.735**	0.671*	0.719	-0.623	0.148	-4.407**	4.456*
Marital Status (Base = Single)							
Married	0.0809	0.268	1.055**	-0.401	0.877	0.279	-0.203
Cohabitant	-0.542	-0.269	0.0562	-2.063	-0.833	-0.425	-0.628
Widow	-0.0821	0.330	1.155	-1.882***	1.328	1.221	0.979
Working time (Base = Only on farm)							
Mostly on farm	-0.435**	0.156	-0.205	0.858***	1.017	-2.742***	-2.129*
Half on farm, half off-farm	-0.257	0.354*	0.351	0.390	1.064	-1.218**	0.374
Mostly off-farm	-0.369	-0.0509	-0.386	-0.476	2.264*	-1.632*	-1.021
Only off-farm	1.209	-0.492			2.377		
Retired	-0.450	1.033*	-0.271	1.089	1.669	-4.164**	-1.390
Education level (Base = Preeschool/None)							
Primary school	0.0830	-0.0983	-0.272	0.207	-0.711	2.078**	0.372
Secondary school	0.00349	0.187	0.0433	0.444	-0.925	1.462	-0.0743
Technical school/Preparatory	0.215	-0.312	-0.402	0.263	-2.253	1.488	-0.0324
Agricultural Technical school	1.124*	0.108	-1.898	7.802***	-3.109	2.342	-1.286
University and Graduate school	0.0528	0.330	0.391	0.782	-2.422	1.966	0.610
Irrigated hectares	0.0150	0.0414	-0.0387	0.0562**	0.0222	-0.225	-0.159
Land is *ejido*	-0.0658	-0.852***	0.972	-2.250*	-2.150***	0.272	1.106
Source of water (Base = Dam)							
Only water from well	-0.211	-0.522**	-0.0721	0.325	0.928	0.824	1.770*
Both water from well and dam	-0.0383	-0.308	1.195**	-0.548	-0.581	-0.423	1.548*
Primary crop alfalfa	-0.0620	0.467*	0.467	0.476	0.507	0.120	-0.0971
Primary crop vine	0.157	0.413*	-0.207	-0.244	-1.002	0.593	0.348
Primary crop maize	0.418	0.690*	0.630	0.292		-2.623***	-1.634
Has. tipo de riego: Rodado	-0.0326	-0.0479	0.00472	-0.0433	0.166	0.128	0.284
Has. tipo de riego: Goteo	-0.0350	-0.0460	0.0683	-0.136***	0.157	0.189	0.201
Municipality (Base = Pabellón de Arteaga)							
Aguascalientes	-0.346	-1.505***				1.586	0.705
Asientos	1.059***	1.100**			2.177**		
Calvillo	-0.322	-0.238	0.350	-0.302			
Cosio	0.262	-1.366				1.332	3.626
El Llano	0.156	-0.223	-0.488	-0.965***	-1.914*	3.162***	0.630
Rincón de Romos	-0.750***	1.197***	-0.0424	-1.802	1.240	1.329	2.455**
San Francisco	1.251	0.175			2.868		
San José de Gracia	-1.163***	2.623***			-0.237	-0.101	2.355**
Tepezalá	-0.00143	0.229	-0.361	-2.161**	2.357**		
Constant	1.720***	3.343***	0.403	5.292***	6.103*	1.480	-0.654
Observations	237	237	78	78	78	81	81
R-squared	0.452	0.538	0.554	0.721	0.690	0.498	0.410

*** p<0.01, ** p<0.05, * p<0.1

Table 16: Cumulative percentage of technology adoption in “IN” sessions

Period	Participants		Percentage	
	Non-adoption	Adoption	Non-adoption	Adoption
1	16	68	19.0	81.0
2	11	73	13.1	86.9
3	7	77	8.3	91.7
4	7	77	8.3	91.7
5	7	77	8.3	91.7

The total numer of participants is 84

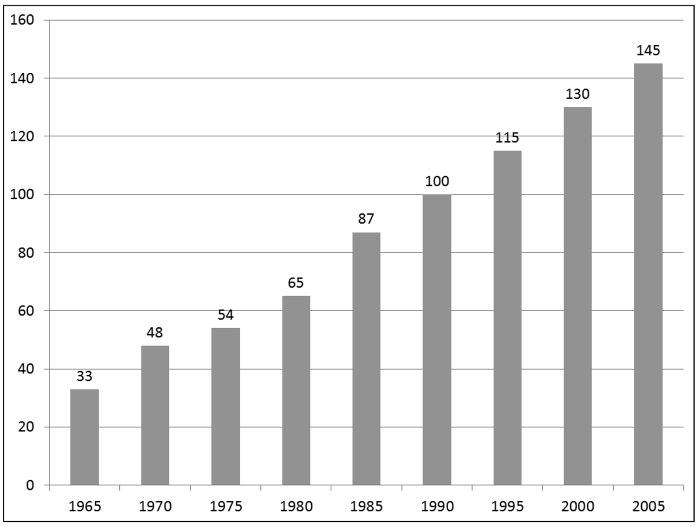
Table 17: Cumulative percentage of agreement defection in “AG” sessions

Period	Participants		Percentage	
	Comply	Defect	Comply	Defect
1	68	20	77.3	22.7
2	37	51	42.0	58.0
3	27	61	30.7	69.3
4	21	67	23.9	76.1
5	18	70	20.5	79.5

The total numer of participants is 88

8 Figures

Figure 1: Average Depth-to-water in Aguascalientes, 1965-2005



Source: Gobierno del Estado de Aguascalientes (2009)

Figure 2: Equilibrium Pumping hours for Myopic, Rational/strategic and Fully Cooperative behaviors

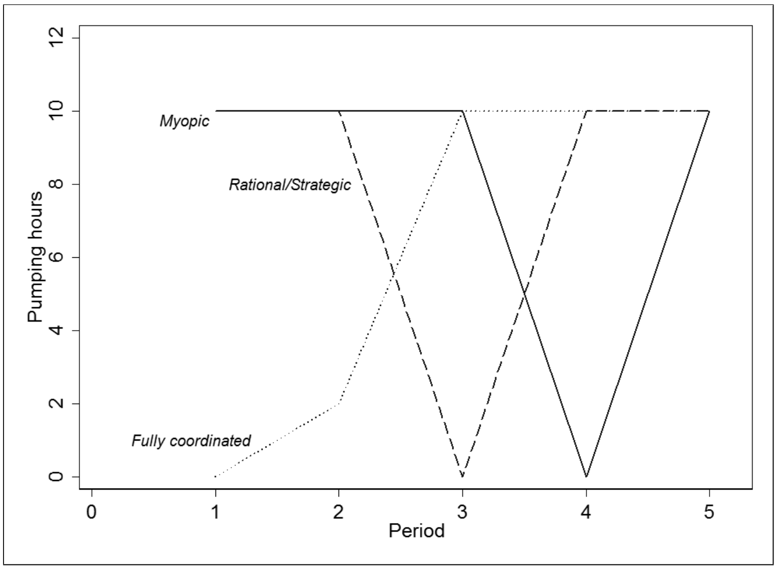


Figure 3: Cost of pumping for Myopic, Rational/strategic and Fully Cooperative behaviors

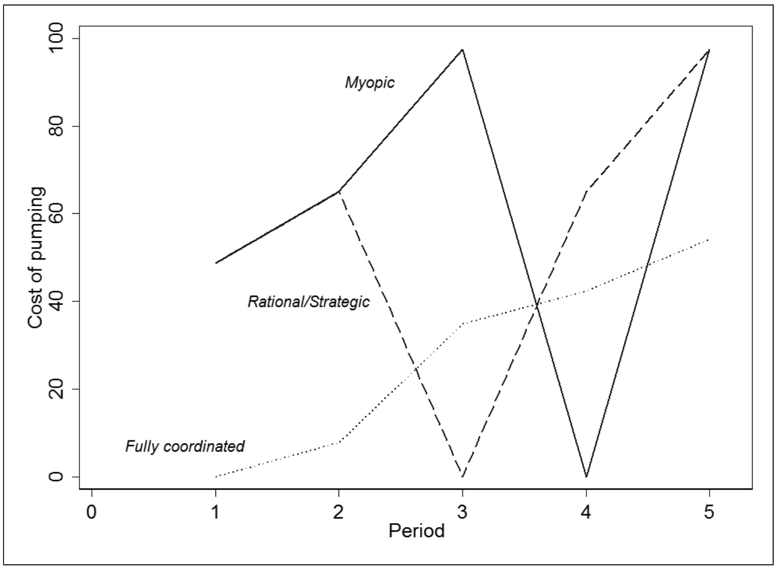


Figure 4: Well depth for Myopic, Rational/strategic and Fully Cooperative behaviors

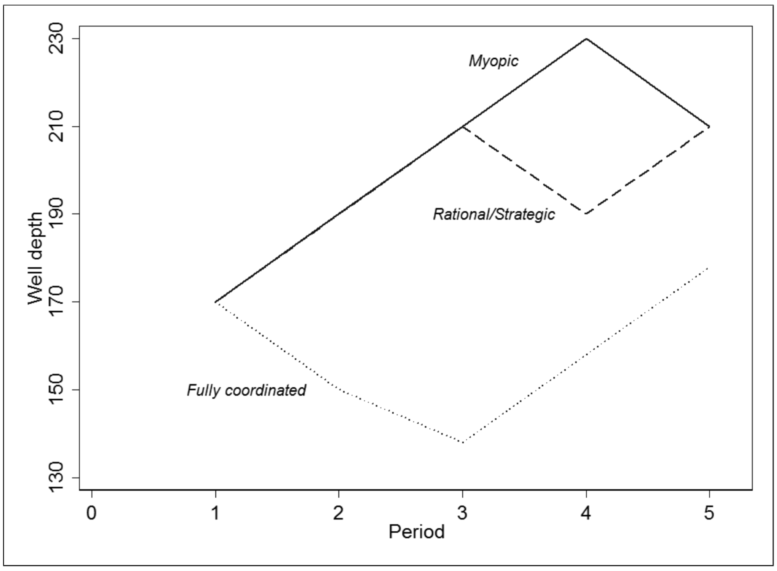


Figure 5: Simulated benefits for Myopic, Rational/strategic and Fully Cooperative behaviors, and fixed arrangements

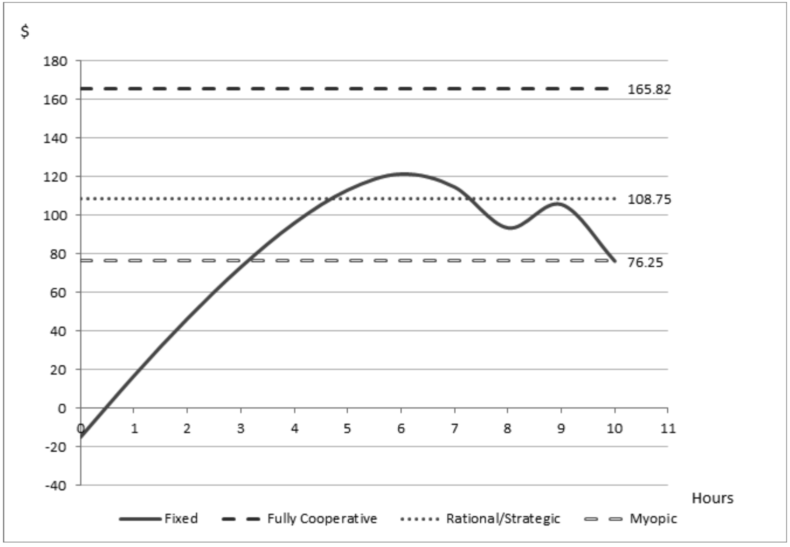


Figure 6: Average individual hours pumped by period and treatment

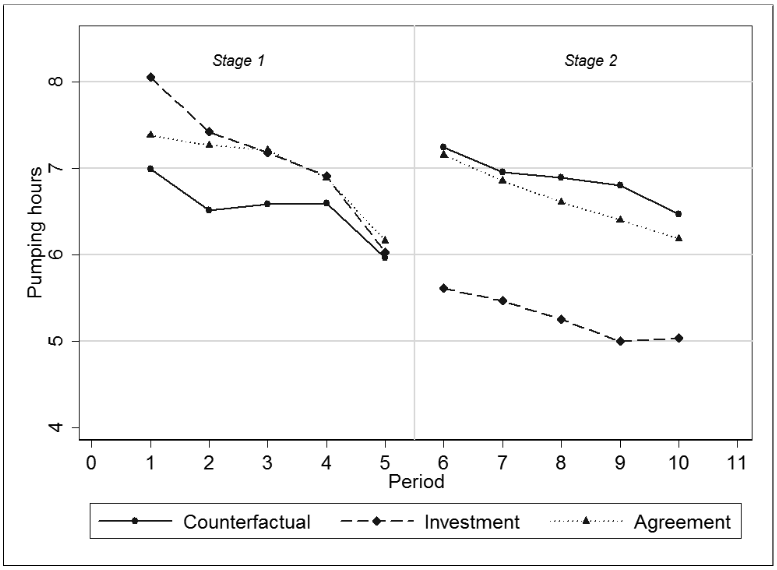


Figure 7: Average individual revenue by period and treatment

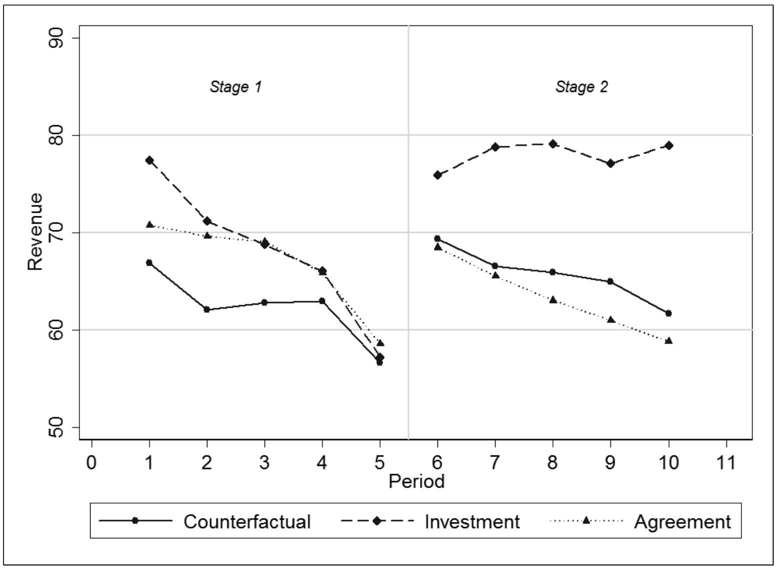


Figure 8: Average individual costs by period and treatment

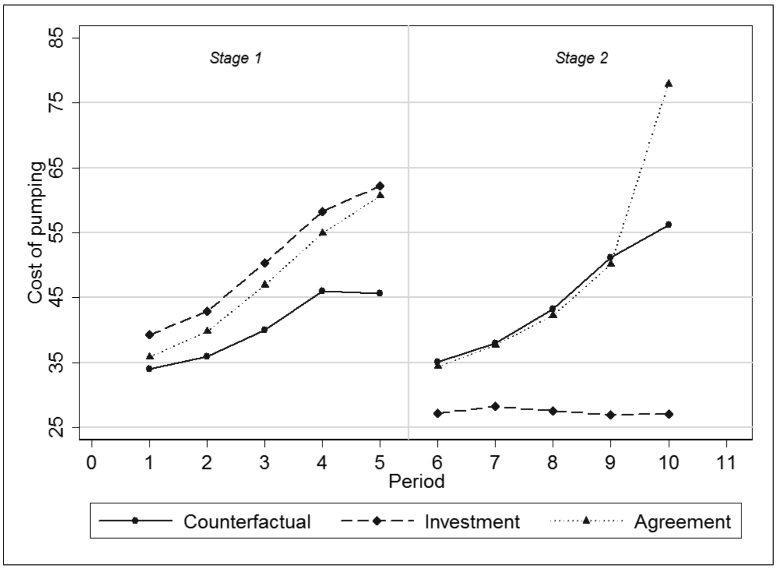


Figure 9: Average individual benefits by period and treatment

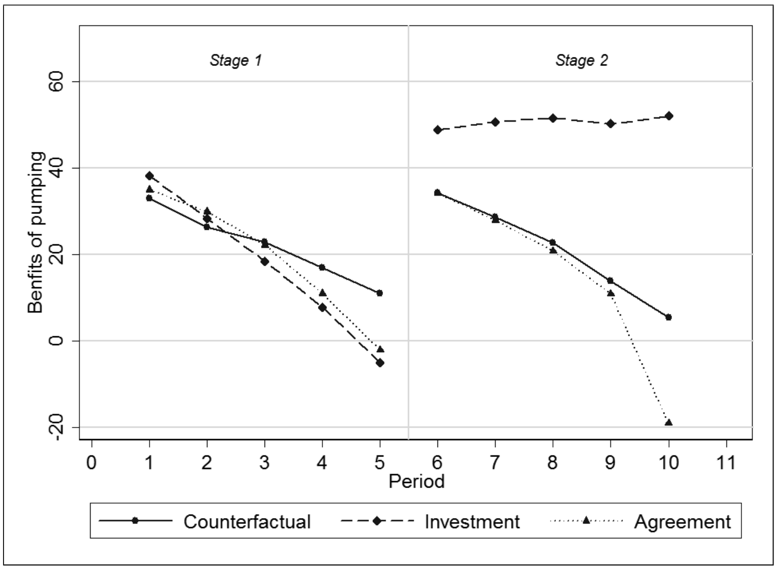


Figure 10: Average well depth by period and treatment

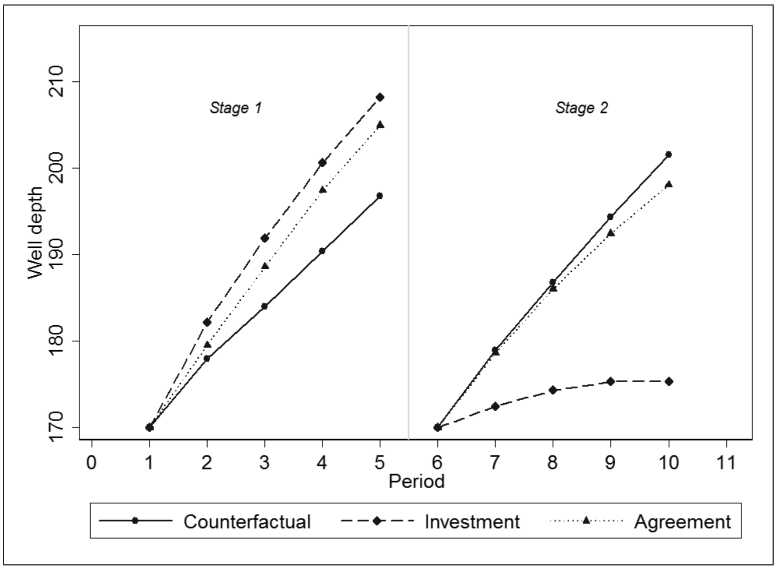
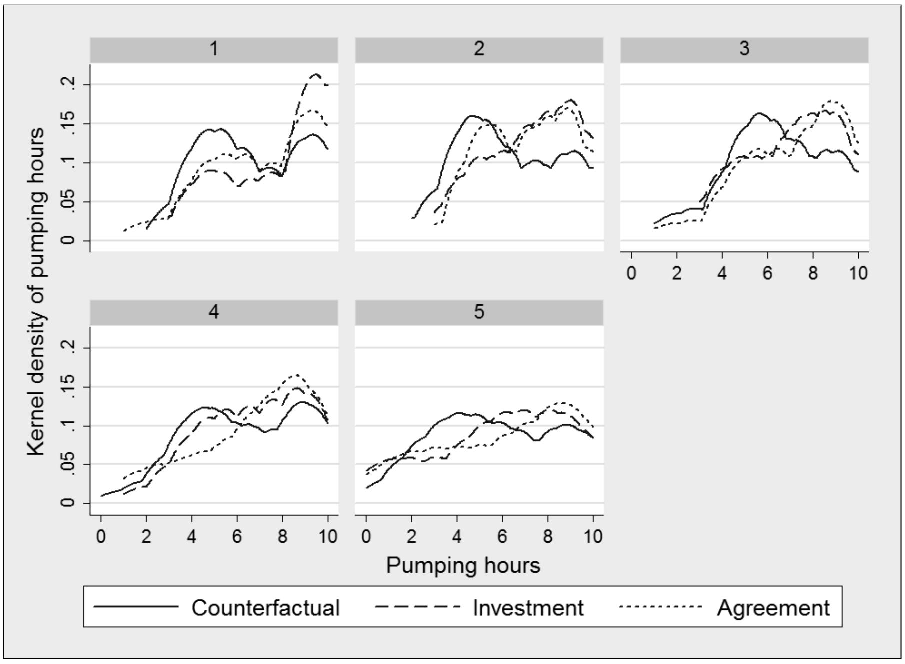
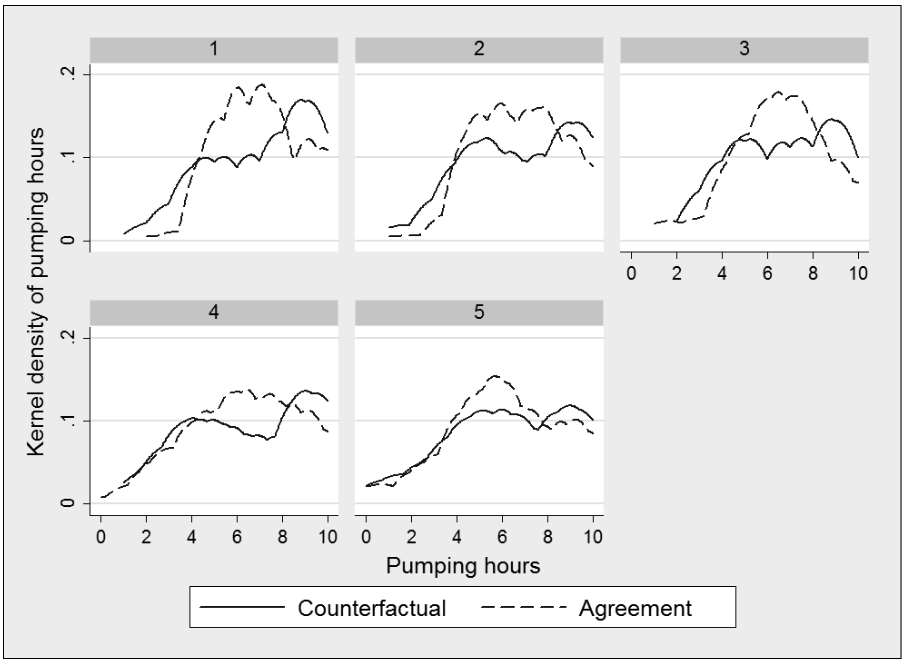


Figure 11: Kernel density estimation of pumping hours in stages 1 and 2 by treatment



a. Stage 1



b. Stage 2

Figure 12: Average individual total benefits by stage and treatment

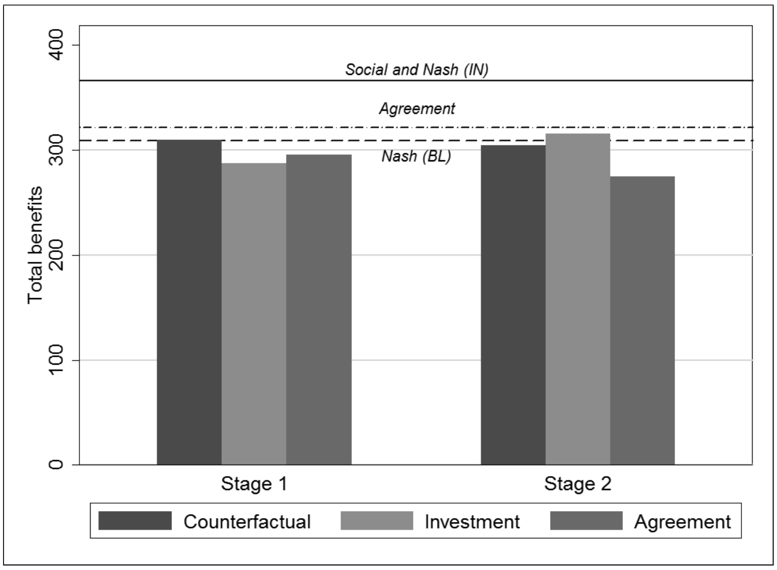


Figure 13: Average final well depth by stage and treatment

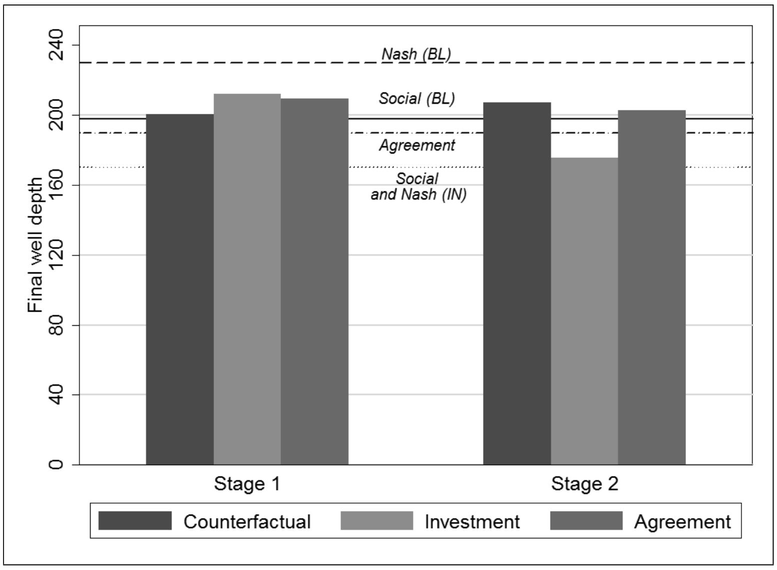


Figure 14: Kernel density estimation of total net benefits in stages 1 and 2 by treatment

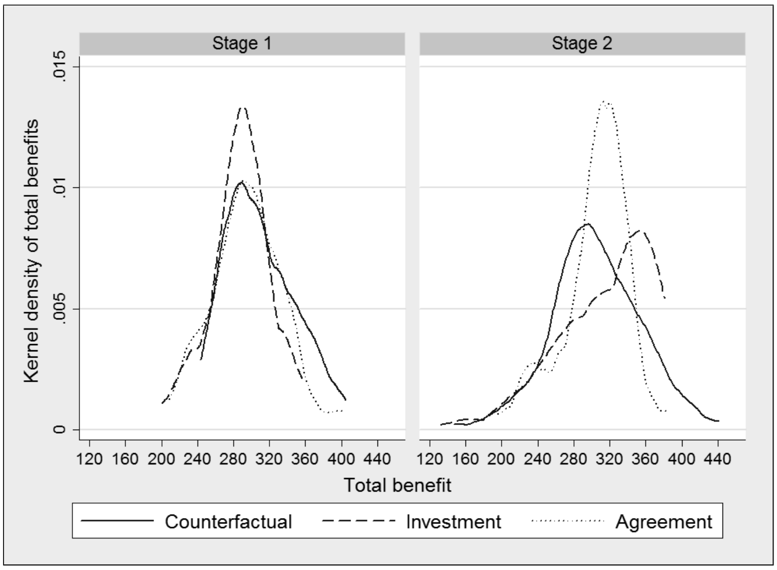


Figure 15: Kernel density estimation of final well depth in stages 1 and 2 by treatment

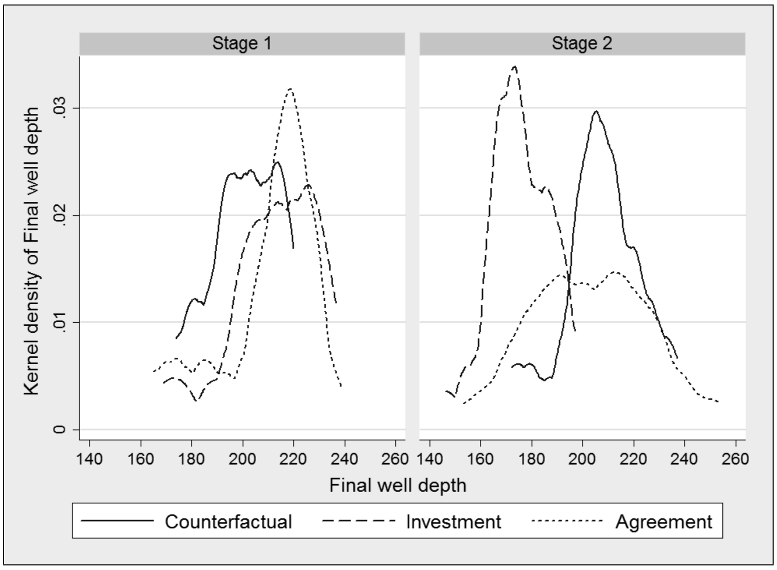


Figure 16: Scatter Plot of Efficiency Index and final well depth in Stage 1

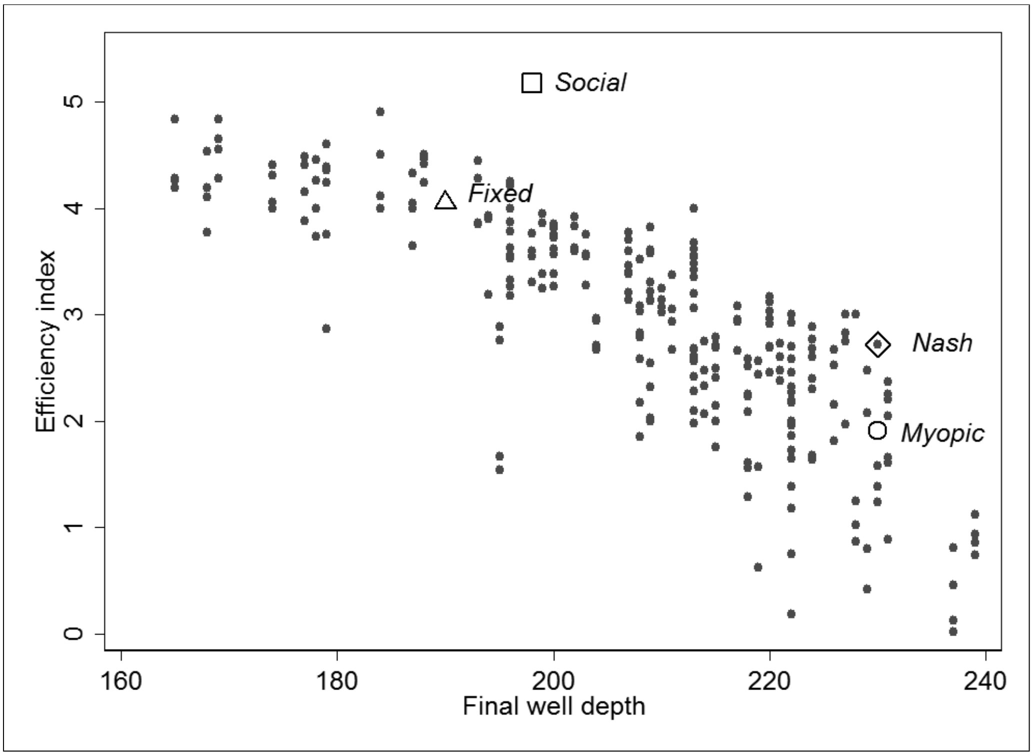
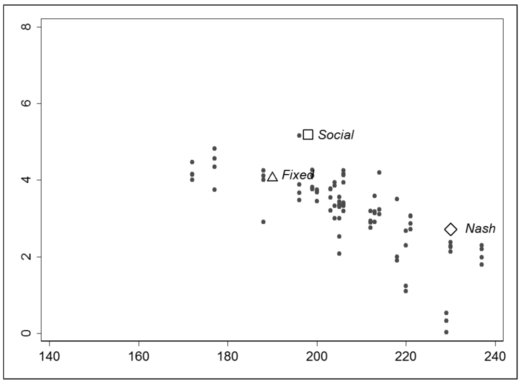
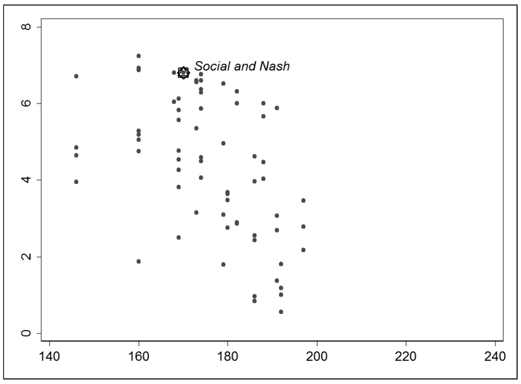


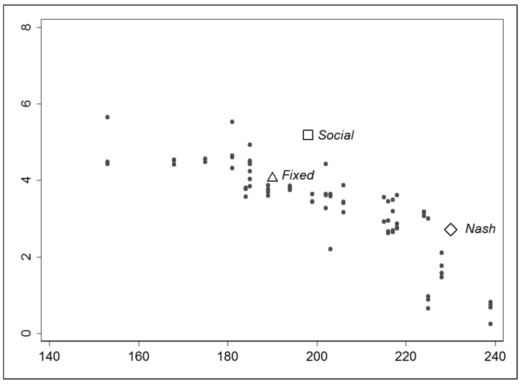
Figure 17: Scatter Plot of Efficiency Index and final well depth in Stage 2 by treatment group



a. Baseline



b. Investment



c. Agreement

Figure 18: Average values of pumped water by level of pumping depth

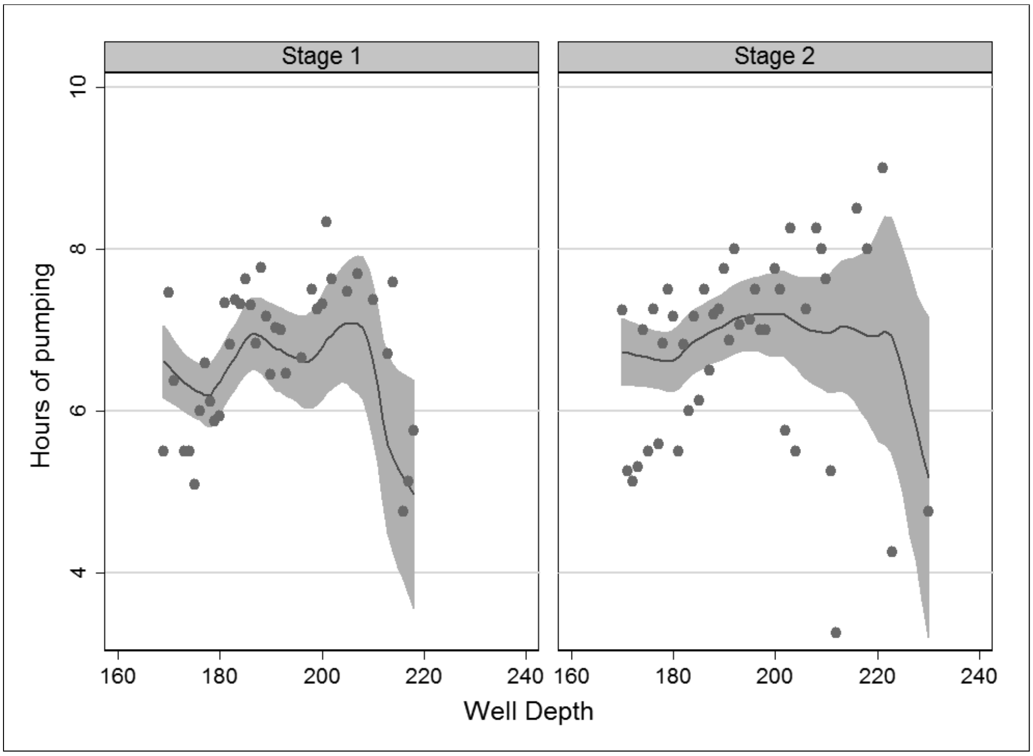


Figure 19: Average values of pumped water by level of pumping depth and period

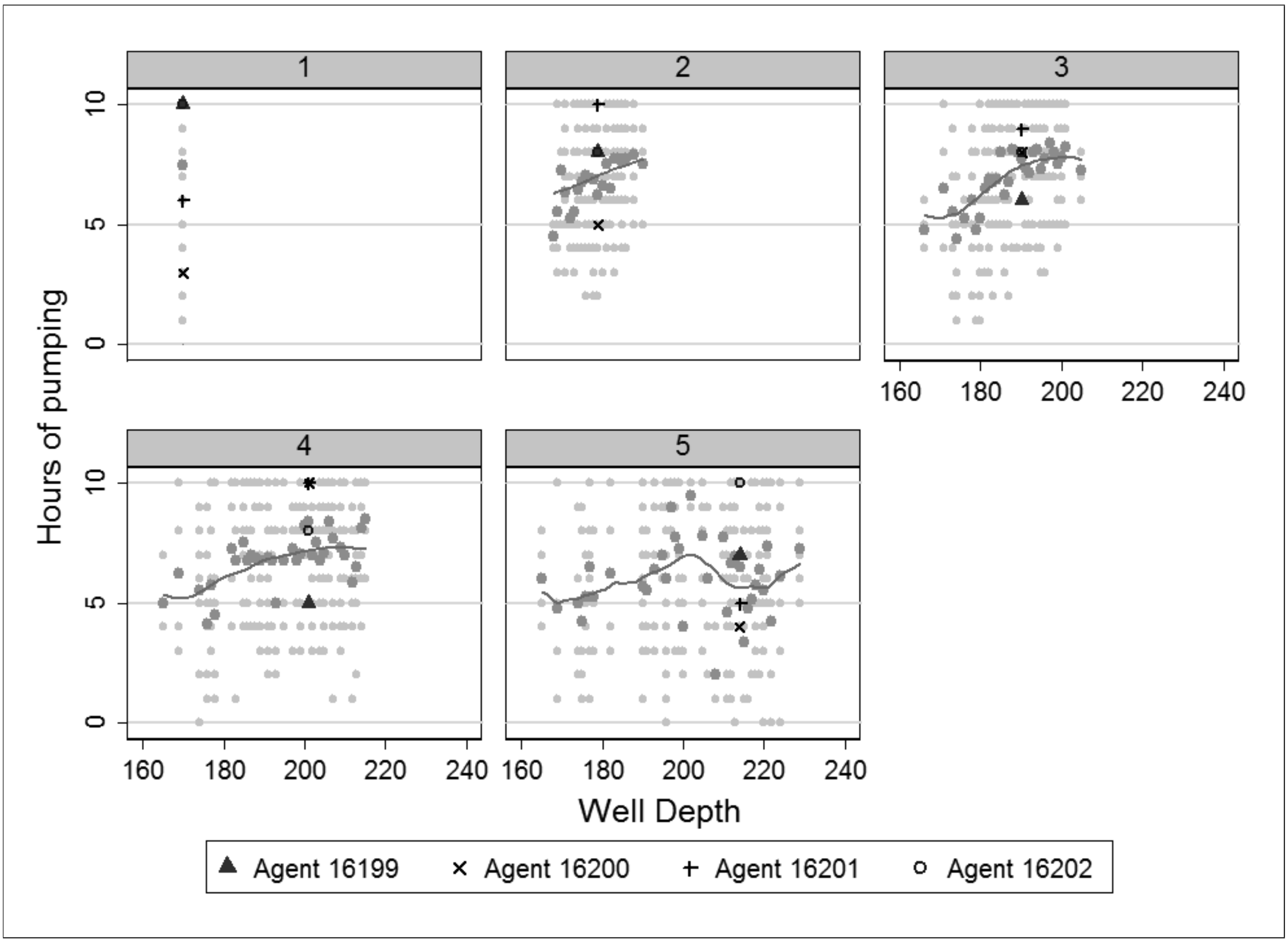


Figure 20: Histogram of agreed values of pumping hours in "AG" sessions

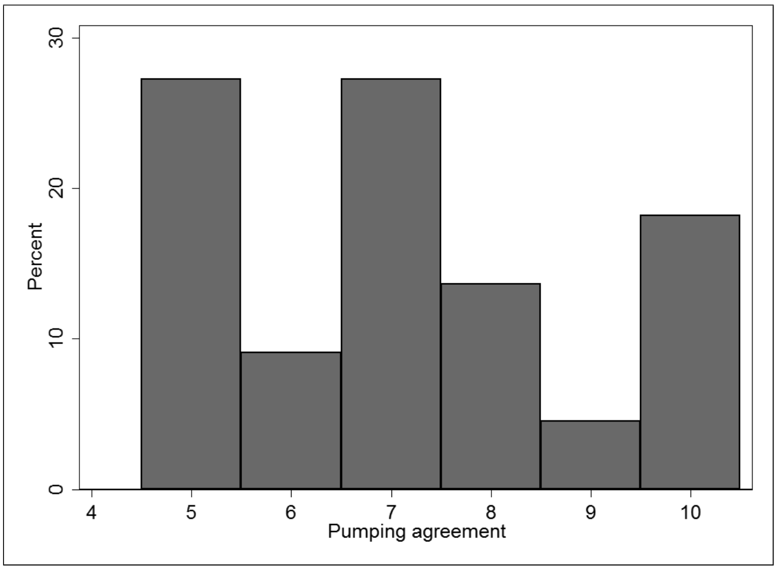


Figure 21: Survival function of agreement

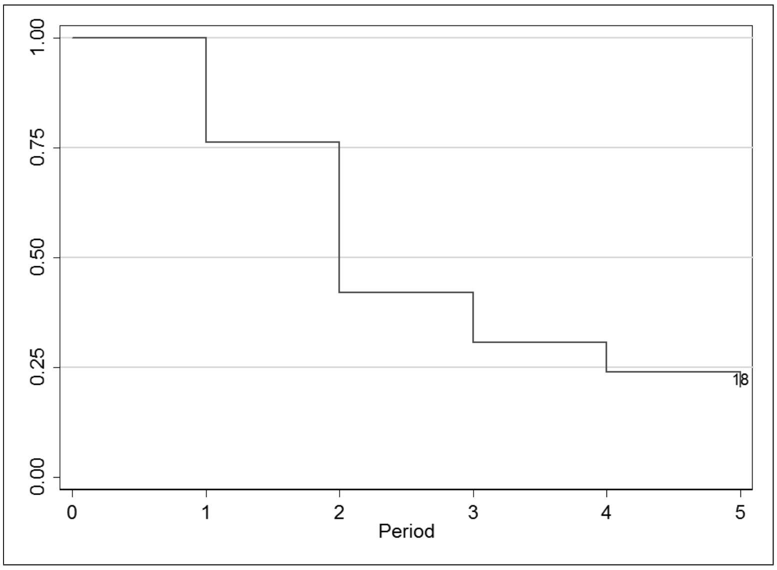


Figure 22: Survival function of agreement, by level of agreement

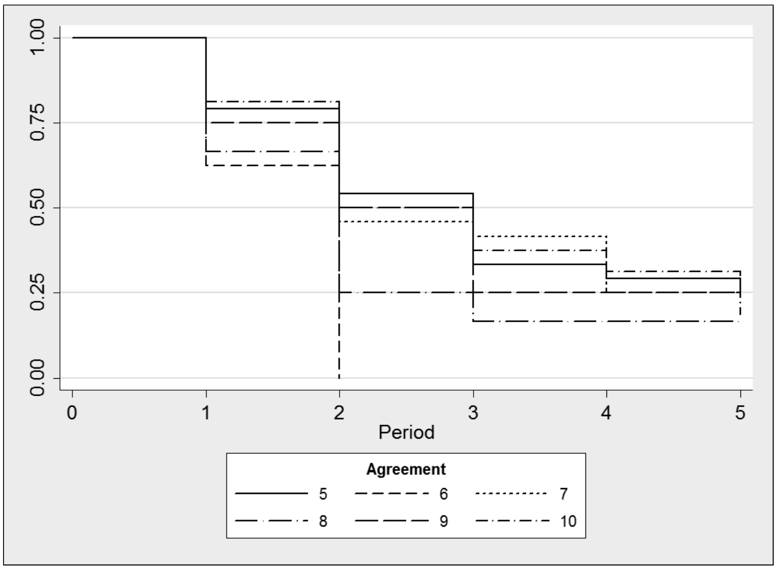
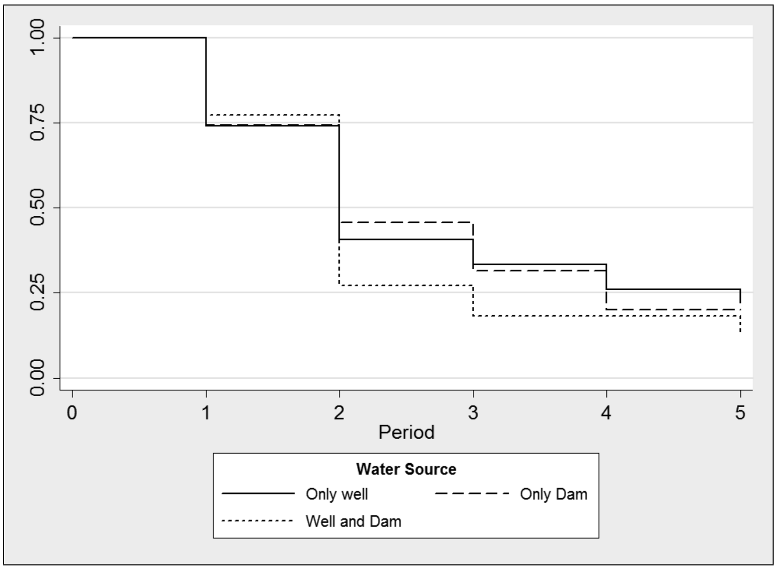


Figure 23: Survival function of agreement, by water source



References

Agaarwal, Rimjhim M. and Tulika A. Narayan (2004), Does inequality lead to greater efficiency in the use of local commons? The role of strategic investment in capacity, *Journal of Environmental Economics and Management*, Vol. 47: 163-182.

Arcidiacono, Peter, Holger Sieg and Frank Sloan (2007), Living Rationally under the Volcano? An Empirical Analysis of Heavy Drinking and Smoking, *International Economic Review*, Vol 48(1): 37-65.

Bardhan, Pranab (2000), Irrigation and Cooperation: An Empirical Analysis of 48 Irrigation Communities in South India, *Economic Development and Cultural Change*, Vol 48 (4): 847-865.

Barham, Bradford L., Jean-Paul Chavas and Oliver T. Coomes (1998), Sunk Costs and the Natural Resource Extraction Sector: Analytical Models and Historical Examples of Hysteresis and Strategic Behavior in the Americas, *Land Economics*, Vol. 74 (4): 429-448.

Bertrand, Marianne, Esther Duflo and Sendhil Mullainathan (2004), How Much Should We Trust Differences-in-Differences Estimates?, *The Quarterly Journal of Economics*, Vol. 119 (1): 249-175.

Brill, Thomas C. and H. Stuart Burness (1994), Planning versus competitive rates of groundwater pumping, *Water Resources Research*, Vol. 30(6): 1873-1880

Brown, Gardner Jr. and Robert Deacon (1972), Economic Optimization of Single-Cell Aquifer, *Water Resources Research*, Vol. 8(3): 557-564

Burt, Oscar R. (1964), Optimal Resource Use Over time with and Application to Ground Water, *Management Science*, Vol. 11(1) Series A: 80-93

Burt, Oscar R. (1967), Temporal Allocation of Groundwater, *Water Resources Research*, Vol. 3(1): 45-56

Burt, Oscar R. (1970), Groundwater Storage Control undr Institutional Restrictions, *Water Resources Research*, Vol. 6(6): 1540-1548

Caldera Ortega, Alex Ricardo (2009), Gobernanza y sustenibilidad: Desarrollo institucional y procesos políticos en torno al agua subterránea en Mxico. Los casos del valle de León y del valle de Aguascalientes, *Ph.D. Dissertation in Political Sciences*, Facultad Latinoamericana de Ciencias Sociales-FLACSO, Mexico City.

Cameron, A. Colin and Pravin K. Trivedi (2005), *Microeconometrics: Methods and Applications*, New York: Cambridge University Press.

Cárdenas, Juan Camilo, Luz Angela Rodriguez and Nancy Johnson (2009), Collective Action for Watershed Management: Field Experiments in Colombia and Kenya, *Documentos CEDE 2009-26.*

Cárdenas, Juan Camilo, Luz Angela Rodriguez and Nancy Johnson (2011), Collective Action for Watershed Management: Field Experiments in Colombia and Kenya, *Environment and Development Economics*, Vol.16: 275-303.

Cárdenas, J.C, M.A. Janssen, and F. Bousquet (2011), Dynamics of Rules and Resources: Three New Field Experiments on Water, Forests and Fisheries, in John List and Michael Price (eds.), *Handbook on Experimental Economics and the Environment*, Edward Elgar Pub (In Press).

Carey, Janis M. and David Zilberman (2002), A Model of Investment under Uncertainty: Modern Irrigation Technology and Emerging Markets in Water, *American Journal of Agricultural Economics*, Vol. 84 (1): 171-183.

Centro de Estudios Sociales y de Opinin Pblica (2008), La Gestin del Agua en los Gobiernos Locales de Mxico, *Documento de Trabajo num. 41*, Mayo.

Comité Técnico de Aguas Subterrneas/Ojocaliente-Aguascalientes-Encarnación (COTAS-OAE) (2006), *Escenarios del Agua 2015 y 2030 en el Acuífero Interestatal Ojocaliente-Aguascalientes-Encarnación: acciones para un desarrollo con sostenibilidad ambiental*, dowloaded from http://www.cotas.org.mx/.

Conrad, Jon M. and Colin W. Clark (1987), *Natural Resource Economics: Notes and Problems*, New York: Cambridge University Press.

Coward, E.W. (1976), Principles in social organization in an indigenous irrigation system, *Human organization*, Vol. 38(1): 28-36.

Collins, Linda M., John J. Dziak and Runze Li (2009), Design of experiments with multiple independen variables: a resource management perspective on complete and reduced factorial designs, *Psychological Methods*, Vol. 14(38): 202-234

Dayton-Johnson, Jeff (2000), Determinants of collective action on the local commons: a model with evidence from Mexico, *Journal of Development Economics*, Vol. 62, pp.181-208.

Dixon, Lloyd Smiley (1989), *Models of Groundwater Extraction with Examination of Agricultural Water Use in Kern County, California*, Doctoral Dissertation, University of California - Berkeley.

Dosi, Cesare and Michele Moretto (2010), Environmental Innovation, War of Attrition and Investment Grants, *International Game Theory Review*, Vol. 12 (1): 37-59.

Gardner, Roy, Elinor Ostrom and James M. Walker (1990), The Nature of Common-Pool Resource Problems, *Rationality and Society*, Vol. 2(3):335-358.

Giordana, Gastón (2008), Wealthy people do better? Experimental Evidence on Endogenous Time Preference Heterogeneity and the Effect of Wealth in Renewable Common-Pool Resources Exploitation, *Document de Recherche, Laboratoire Montpelliérain d' Economie Théorique et Appliquée*, No.2008-10.

Gisser, Micha and David A. Sánchez (1980), Comptetion Versus Optimal Control in Groundwater Pumping, *Water Resources Research*, Vol. 16(4):638-642.

Gobierno del Estado de Aguascalientes (2009), *Sistema de Indicadores Ambientales del Estado de Aguascalientes*, Aguascalientes, México: Gobierno del Estado de Aguascalientes and Instituto del Medio Ambiente.

Hackett, Steven, Edella Schlager and James Walker (1994), The Role of Communication in Resolving Common Dilemmas: Experimental Evidence with Heterogenous Appropriators, *Journal of Environmental Economics and Management*, Vol. 27: 99-126.

Hardin, Garrett (1968), The Tragedy of the Commons, *Science*, 162: 1243-1248.

Houser, Daniel, Michael Keane and Kevin McCabe (2004), Behavior in a dynamic decision problem: An analysis of experimental evidence using Bayesian type classification algorithm, *Econometrica*, Vol. 72 (3): 781-822

Instituto Nacional de Estadística y Geografía (2009), *Estados Unidos Mexicanos, Censo Agropecuario 2007, VII Censo Agrícola, Ganadero y Forestal*, México D.F.: INEGI.

Janssen, Marco, John M. Anderies, J.C. Cardenas (2011), Head-enders as stationary bandits in asymmetric commons: Comparing irrigation experiments in the laboratory and the field, *Ecological Economics*, Vol. 70 (9): 1590-1598.

Jevons, W. S. (1865), *The Coal Question*, London: Macmillan and Co.

Koundouri, Phoebe (2004), Current Issues in the Economics of Groundwater Resource Management, *Journal of Economic Surveys*, Vol 18(5): 703-740

Koundouri, Phoebe (2004), Potential for groundwater management: Gisser-Sánchez effect reconsidered, *Water Resources Research*, Vol. 40, W06S16, doi:10.1029/2003WR002164.

Lee, Myoung-Jae (2005), *Micro-Econometrics for Policy, Program and Treatment Effects*, New York: Oxford University Press.

Lichtemberg, Erik (1989), Land Quality, Irrigation Development and Cropping Patterns on the Northern High Planes, *American Journal of Agricultural Economics*, Vol. 71(1): 187-194.

Madani, Kaveh and Ariel Dinar (2012), Non-cooperative institutions for sustainable common pool resource management: Applications to groundwater, *Ecological Economics*, Vol. 74: 34-45.

McGinnis, Michael D., ed. (2000), *Polycentric Games and Institutions: Readings from the Workshop in Political Theory and Policy Analysis*, Ann Arbor, MI: The University of Michigan Press.

Moreno-Sánchez, Rocío del Pilar and Jorge Higinio Maldonado (2010), Evaluating the role of co-management in improving governance of marine protected areas: An experimental approach in the Colombian Caribbean, *Ecological Economics*, Vol. 69: 2577-2567.

Moretto, Michele (2000), Irreversible investment with uncertainty and strategic behavior, *Economic Modelling*, Vol. 17: 589-617.

Nieswiadomy, Michael (1985), The Demand for Irrigation Water in the High Plains of Texas, 1957-1980, *American Journal of Agricultural Economics*, Vol. 67(3): 619-626

Negri, Donald H. (1989), The Common Property Aquifer as a Differential Game, *Water Resources Research*, Vol. 25 (1): 9-15.

Ostrom, Elinor (1986), Issues of definition and theory: some conclusions and hypothesis, *Proceedings of the conference on common property management*, National Research Council, Washington D.C.: National Academy Press.

Ostrom, Elinor (1990), *Governing the Commons: the evolution of institutions for collective action*, New York: Cambridge University Press.

Ostrom, Elinor (1992), *Crafting institutions for self-governing irrigation systems*, San Francisco, CA: Institute for Contemporary Studies University Press.

Ostrom, Elinor and Roy Gardner (1993), Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work, *The Journal of Economic Perspectives*, Vol. 7(4): 93-112.

Ostrom, Elinor (2002), Chapter 24: Common-Pool Resources and Institutions: Toward a Revised Theory, in Bruce Gardner L. and Gordon C. Rausser (eds.), *Handbook of Agricultural Economics, Vol. 2*, Amsterdam: Elsevier Science B.V.

Peterson, Jeffrey M. and Ya Ding (2005), Economic Adjustments to Groundwater Depletion in the High Planes: Do Water-Saving Irrigation Systems Save Water?, *American Journal of Agricultural Economics*, Vol. 87(1): 147-159.

Pfeiffer, Lisa (2009), *Three Essays on the Economics of Groundwater Extraction for Agriculture: Property Rights, Externalities and Policy*, Doctoral Dissertation, University of California - Davis.

Provencher, Bill and Oscar Burt (1993), The Externalities Associated with the Common Property Exploitation of Groundwater, *Journal of Environmental Economics and Management*, Vol. 24: 139-158.

Rodrguez-Haros, Benito and Jacinta Palerm-Viqueira (2007), Before transference: Handing over water districts, *Agricultura, Sociedad y Desarrollo*, Vol. 4 (2): 105-125.

Rubio, Santiago J. and Begoña Casino (2003), Strategic Behavior and Efficiency in the Common Property Extraction of Groundwater, *Environmental and Resource Economics*, Vol.26(1): 73-87

Scheierling, Susanne M., Robert A. Young and Grant E. Cardon (2006), Public subsidies for water-conserving irrigation investments: Hydrologic, agronomic, and economic assessment, *Water Resources Research*, Vol. 42(3), W03428.

Swallow, Brent, Nancy Johnson, Rurth Meinzen-Dick and Anna Knox (2006), The challenges of inclusive cross-scale collective action in watersheds, *Water International*, Vol. 31(3): 361-376.

Trawick, Paul (2003), Against the Privatization of Water: An Indigenous Model for Improving Existing Laws and Successfully Governing the Commons, *World Development*, Vol. 31(6): 977-966.

Walker, James M., Roy Gardner and Elinor Ostrom (1991), Rent Dissipation and Balanced Deviation Disequilibrium in Common Pool Resources: Experimental Evidence, in Reinhard Selten (ed.), *Game Equilibrium Models II: Methods, Morals and Markets*, Heidelberg: Springer-Verlag Berlin.

Wang, Chenggang and Eduardo Segarra (2011), The Economics of Commonly Owned Groundwater When User Demand Is Perfectly Inelastic, *Journal of Agricultural and Resource Economics*, Vol 36(1): 95-120

Ward, Frank A. and Manuel Pulido-Velazquez (2008), Water conservation in irrigation can increase water use, *Proceedings of the National Academy of Science*, Vol. 105(47): 18215-18220.

Worthington, Virginia E., Oscar R. Burt and Richard L. Brustkern (1985), Optimal Management of a Confined Groundwater System, *Journal of Environmental Econmics and Management*, Vol. 12(3): 229-245