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An Exchange Market of Water Rights for Irrigation in Tunisia: Case of Asymmetric Information on Water Quality

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Abstract Tunisia, due to its location between the Mediterranean and the Sahara, is an arid country on most of its territory. Indeed, there is a marked difference between the availability of water in the North of the country and its use for irrigation in the Center. This difference, combined with the variability of the Mediterranean climate, makes water resources scarce and unequally distributed in time and space. These problems led me to search for an alternative that reduces water consumption. The present paper heads towards the creation of markets for irrigation water rights in asymmetric information on the quality of this resource to minimize water consumption. Since important consequences result from the asymmetry of information in a water market, in the case where one of the parties in a market (buyer or seller) has more information than those of the other side. The purpose of this work is therefore to consider the exchange market of water rights to measure the economic efficiency of water markets on the one hand in the presence of total asymmetry of information on water quality and on the other hand in the presence of variable costs of information. And then to see what better strategy can reduce water consumption during years of scarcity. In response, we proposed to conduct a laboratory experiment (we used 8 sessions included 32 exchange periods), to test a variety of auction treatments and to measure the impact of unequal distribution of the cost of information on water quality between the different users (buyers and sellers). Results show that small changes in the distribution of information can have a large and considerable impact on the economy. The higher the information cost, the lower the number of high-quality permits sold, and thus the lower the efficiency of the market. Thus, it can be concluded that the high responsiveness of the demand for information on the quality of the resource suggests that pricing policies can be a potential instrument to minimize water consumption.

Keywords Auction, Asymmetric Information, Irrigation, Water Quality, Price, Field Experiments

1. Introduction

In Tunisia, with increasing demands due to population and economic growth, water is recognized as a *scare* in the economic sense that there are limited supplies for given uses. The problem of scarcity has led us to adopt a sustainable management policy that ensures a *reduction in water consumption.*

A water market makes it possible to sell and buy the resource, to access available information, to negotiate and to exchange offers.

And because any promotion of sustainable water management policy must first define the rights of water use, so to guarantee the efficiency of water markets an organization of the exchange of these rights must be considered.

The experimental literature has looked a lot at the behavior of markets with asymmetric information on water quantities and prices, but very little has considered markets with *asymmetric information on the quality* of this resource.

So the objective of this work is therefore to consider the exchange market of water rights in asymmetric information on water quality to measure the efficiency of water markets on the one hand in the presence of total asymmetry of information on water quality and on the other hand in the presence of variable costs of information. And then to see what better strategy can reduce water consumption during years of scarcity and can better distribute this resource.

In response, we are organizing this work in three main sessions. First, we present an overview of the literature on the information asymmetry studied by the water markets and a descriptive analysis of the existing relationship between the information asymmetry and the cost of information on water quality. Next, we run an auction in a laboratory and test the effectiveness of the market in the presence of information costs. The results of this auction will be analyzed in the third session and used in econometric modeling.

Information asymmetry is identified as an unequal distribution of information between two agents. This unequal distribution leads the agent with the most information, such as the buyer, to earn a profit from their private information. Having a lot of information comes from the limited skills of individuals. In addition, in the presence of information symmetry, consumers are burdened with increasing information. Indeed, consumer attention and not information which has become a scarce resource.

Kihlstrom et al. [1], Bommier et al. [2] generally studied the demand for product quality information. He gives this request for information in two aspects. First, it is a derivative request. It only persists because it gives consumers the ability to make better choices in purchasing other goods. Second, the demand for information only exists when the quality of the products is not known in advance or is uncertain.

Grossman et al. [3], Bester et al. [4] analysed a market model with information costs on the quality of the good (dynamic game with incomplete information). There are two types of suppliers of goods (suppliers of lower quality goods q_L and suppliers of higher quality goods q_H). Buyers know very well that sellers offer the quality q_H with the probability $p \in [0,1]$ and the quality q_L with the probability $(1 - p)$.

When exchanging goods, and depending on the price offered, each applicant tries to test the quality of the good by purchasing a fixed cost $k > 0$, which perfectly identifies the quality. The authors then proved that the market equilibrium depends on the impressions of agents on the strategies and behaviours of other agents.

Plott [5] studied the efficiency of markets whose data on consumer needs are known to sellers. In their experience, and before buyers start buying, they can, at no cost, request information from different sellers to get an idea of their needs. The exchange market between sellers weakens the sellers' incentive to defraud (through the over-prescription of services) and increases the efficiency of the market.

Cason et al. [6] analysed reputation, self-declaration and certification as treatments that serve to increase the efficiency of markets with adverse selection. Reputation and self-reporting evolve on average the efficiency of the market. Certification is the only process where the majority of units traded are of superior quality.

Thabet et al. [7] studied a water rights system in Tunisia with asymmetric information on water productivity. They showed that with increasing demand for water among users due to population and economic growth, the Tunisian government made many policies and technical measures, such as institutional reforms, that improve the efficiency of water delivery and water pricing policies. They had been observed that the cost of water generated and delivered is not consistent, making the establishment of a water pricing scheme difficult. Besides, the water authority had no good information about the water productivity which conducts to asymmetric information to both authorities and farmers.

The authors then proved that the water rights system could be an alternative to solve the problem of asymmetric information and to improve the economic efficiency.

Bouchrika et al. [8] tested the significance of the variable quality as an important determinant of global and regional drinking water demand function in Tunisia. They have used a sample of 1200 consumers, to measure with econometric estimates the importance of quality on water demand functions. Estimates showed that demand functions in global regions revealed the importance of quality as a key determinant of water quantities demand. They had shown that in Greater Tunis water quality is not significant. However, in the regions of Sousse and Gabes, water quality is an important factor in water demand.

In our case study, our problem is to know how information on water quality affects the water permit market. In addition to the market's reaction to a total information asymmetry, it is interesting to study the behaviour of agents in the presence of variable information costs. We present in the following sections an experimental study allowing us to provide some answers to this question.

How does information on water quality affect the market for water rights and minimize the consumption of this resource?

2. Materials and Methods

2.1. The Experimental Protocol

In our study, the experimental protocol used here is similar to that of Cason et al. [6]. The subjects are mainly economics students from the Faculty of Economics and Management of Sousse, and from the LAMIDED laboratory located at the Higher Institute of Management of Sousse, selected by e-mail. Each session has 8 participants: 4 sellers and 4 buyers. The role of each participant is randomly selected. The experiments were carried out at the LAMIDED laboratory in Sousse where the subjects were isolated from each other by partitions.

ZTREE software was used for programming and then running the experiment.

The use of partitions as well as software therefore makes it possible to control the environment in which the experiment takes place. The roles are distributed to all participants who receive their private information sheet including for buyers the trade-in values and for sellers the costs generated by the manufacture of the goods.

We considered a market with sellers and buyers and with induced preferences[1]. We used 8 sessions, each lasting 2 to 3 hours[2]. Each session included 32 exchange periods, except the first session (only 28 periods of which the first 5 periods constitute a trial period). The exchanges were defined and carried out in points which were at the end of the experience converted into dinars. This conversion rate is 1 point = 0.003 dinars for sellers and 1 point = 0.012 dinars for buyers. The average earnings of each participant were 30 dinars and will be paid at the end of the experience.

During each trade-in period, sellers can offer up to two Types I (Lower) water permits or two Types S (Upper) water permits for sale. Public information is that S permits are more expensive than I permits but only sellers know the true values of the costs.

In our experience, each permit S costs 150 points to sellers and each permit I costs 50 points. Likewise, for buyers, trade-in values for S permits are greater than trade-in values for I permit. This is public information, but only buyers know their true values.

In addition, the trade-in value of the first permit S is set at 360 points, that of the second one is set at 330 points and that of the third one is worth 300 points. Likewise, for I permit, the first value is 215 points, the second is 200 points, and finally the third is 185 points.

In order to move away from the heterogeneity problem, we choose buyers and sellers who had identical trade-in values and costs. In fact, buyers want to buy S permits if the price is 115 to 145 points higher than the price of I permits.

At a perfectly efficient market equilibrium, of which only type S permits are traded, and theoretically the equilibrium price is 330 of which 10 permits are sold. For all participants, this balance considers a total surplus of 1980 points. At equilibrium, 10 water permits S are sold at the price of 330 for sellers, the 10 permits S give a surplus of (330-150) = 180 per water permit and that is to say 180 * 10 = 1800 points of surplus for sellers. For buyers, the first 6 permits S have a reserve price of 360 points, although the next 4 permits have a reserve price of 330 points. Buyers generate a profit of (360-330) = 30 points per permit on the first 6 permits and a surplus of (330-330) = 0 on the last 4 permits. As a result, the total profit of buyers is 30 * 6 + 0 * 4 = 180. At equilibrium, the total gain is equal to 1980 points; 1800 for sellers and 180 for buyers.

Likewise, with inefficient market equilibrium, where only Type I permits are sold, the equilibrium price is 200 points with 10 permits traded. This balance does generate a total profit of 1590 points.

Through the studies of Cason et al. [6], we drew the following definition. The efficiency of the market is calculated as the ratio between on the one hand the sum of the real profits of each of the subjects in the current session and on the other hand the sum of the theoretical profits that each of the subjects would have gained if only the permits of the superior type S had been sold at their equilibrium price in perfect information (that is price of 330), and which generates a surplus of 1980 points. Market efficiency at inefficient equilibrium corresponds to a state where only permits of lower type I are traded. It is then 1590/1980 = 0.803.

In addition to these wins, buyers will earn a bonus of 50 points each period and an initial gain at the start of the experience of 200 points. The bonus and the additional gain protect against the appearance of any loss effects throughout the experience. Also, buyers have the right to not purchase a permit within a period. Their non-purchase gain is therefore equal to 10 points.

In approaching the problems of water management, the literature has always studied the quantity and the quality of water as two distinct and independent problems.

In our present work, we consider a water market with certain information on the quantity of water to buy from sellers but with uncertain information on the quality of the water where the buyer in this case has the right to buy information that is more or less expensive on quality. Our goal thereafter is to measure the efficiency of the market, the behaviours and decision-making of participants when information costs are increasing.

Starting from this objective, we can formulate the following two assumptions for the water and information markets:

- ***H1****: The higher the cost of requesting information, the lower the number of high-quality permits sold, and thus the lower the efficiency*[3] *of the market.*
- ***H2****: The higher the cost of requesting information, the fewer buyers will invest in the information.*

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[1] In the experiments with induced preferences, we fix the recovery values of the agents (they are set by the experimenter) and we compare the different market treatments (we look at the offer behaviour in a second-price auction and in a first-price one)

[2] The experience was a bit long because there was no time limit for each answer. We were fear that putting limits on response times would lead to biased decisions.

[3] We define market efficiency as the ability of the market to offer high quality permits. In our experience, it is the ratio between the sum of the profits of all the participants and the sum of the surpluses of the participants if only the higher quality permits had been exchanged (Holt, 1995, p.358).

Table 1. Treatments

Treatment	Sessions	Place	Characteristics	Absolute cost of information
REF	*REF_1* *REF_2* *REF_3*	Isg_Sousse Fseg_Sousse Fseg_Sousse	Total asymmetry of information on water quality between sellers and buyers	« ∞ »
SUP	SUP_1 SUP_2	Fseg_Sousse Fseg_Sousse	Buyers have the ability to obtain information at a high cost	50 points
INF	INF_1 INF_2 INF_3	Fseg_Sousse Fseg_Sousse Fseg_Sousse	Buyers have the ability to obtain information at a low cost	15 points

2.2. Econometric Modelling and Data Processing

Table 1 summarizes 3 treatments (REF, SUP, INF) which are used during an auction. Our main objective is to measure the efficiency of the market, that is to say the gains that all participants can gain when selling water permits and when the costs of information on water quality are growing.

In REF treatment, we study the efficiency of the market in the presence of total asymmetry of information on water quality. In this process, buyers can not know the quality of the water permits, and so the cost of purchasing the information is called "infinite".

In the SUP processing, we treat the efficiency of the market in symmetry of information on the quality, that is to say in the presence of high information costs which is equal to 50 points (the trade-in value of a permit of upper type S (respectively lower type I) is 360 (respectively 215) at most, and therefore the maximum gain for buyers for a type S permit compared to another type I permit is 360 -215 = 145. The result is that 34.5% of the greater surplus when a permit S is purchased rather than a permit I.

In the INF processing, we measure the efficiency of the market in symmetry of information on quality that is to say in the presence of low information costs which are equal to 15 points. The result is about 10% of the greater surplus of buying a permit S rather than a permit I.

In our experience, we have conducted a total of 8 sessions; three sessions for each of the REF and INF treatments, and two sessions for the SUP treatment.

At the start of each period, sellers present the number of permits, the unit price as well as the type of permits they want to sell. Thereafter this table which gathers all the offers (price and permits) will be given to the buyers in a random order. Buyers therefore randomly select their purchases [9].

Each session has 4 phases:

- In phase 1, information on the type of water permits is revealed after each period.
- In phase 2, the information on the type of water permits is revealed after 4 periods.
- In phase 3, the information on the type of water permits is revealed after 8 periods.
- In phase 4, the information on the type of water permits is revealed after 16 periods.

This method gave buyers the chance to know and learn the rules of the game, the methods of calculating profits, especially during the first 4 periods of testing[4].

2.3. The Models

In this project we analyze, on the one hand, the efficiency of the water market in the presence of variable information costs and the probability for sellers to offer type S permits and on the other hand, the behavior of buyers when requesting information.

2.3.1. Market Efficiency and the Probability of Offering Type S Permits

Depending on the treatment considered, two models are ready to apply; a perfect information model and an adverse selection model.

Perfect information model:

In this model, the permits are sold at the market clearing price. S permits are sold for 330 and I permits for 200. As, S permits offer a higher profit than offered by I permits, so the predicted balance is that only S permits will be sold at their equilibrium price 330.

So the sessions of the INF processing are able to move towards the perfect information model.

Bester et al. [4] prove that as the cost of information becomes negligible, the equilibrium approaches full information and prices become perfectly informative.

Adverse selection model:

In this model developed by Akerlof. [10], Type S permits are excluded from the market because buyers, who cannot verify the quality of the permits, will not agree to pay a price greater than the price of the average quality in the market. So high quality sellers can no longer put good quality permits on the market because only bad quality permits will be sold. At this equilibrium, only Type I permits will be sold at the equilibrium price of 200. In addition, the REF and SUP treatment sessions are able to approach this equilibrium.

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[4] These first 4 periods gave rise to gains due to the bonus of 50 points / period and the start of experience gain of 200 points which allows moving away from the effect of losses during these first periods.

2.3.2. The Behavior of Buyers when Requesting Quality Information

Here we study the reaction of buyers when requesting information on the quality of water according to the cost of the information on the one hand and on the other hand according to the price offered to the market.

Effect of the cost of information on the demand for information:

Regarding the demand for quality information, the law of demand proves that the more expensive the information, the less participants will buy information. The demand for information in SUP processing is expected to decrease compared to the demand for information in INF processing.

Effect of price on demand for information:

Regarding the request for information on the quality of permits, the effect of the price of water permits varies widely. As a result, the relationship of demand for information to price is not linear. Indeed, we follow the logic that exists:

- A price below which buyers will not invest in purchasing quality information. Even if the water permit is of lower type I, the purchase of the permit offers in all cases a greater gain than the profit of no purchase, and
- A price above which buyers will not invest in purchasing quality information. Even if the water permit is higher type S, the information is in any case too expensive. Buying the permit offers a lower profit than the non-buying profit.

Based on the model of Bester et al. [4], we adopt the following hypotheses:

The request for information is null if the price of the permit belongs to:

- to the set] -∞, 200] Ụ [350, + ∞ [if the buyer has not yet purchased a permit within the period;
- to the set] -∞, 190] Ụ [320, + ∞ [if the buyer bought 1 permit in the period;
- to the set] -∞, 175] Ụ [280, + ∞ [if the buyer bought 2 permits during the period.

3. Results and Implications

Our experience with the auction is summarized in Table 2 which shows the number of Type I and S permits offered and the efficiency of the market per treatment and over a specified period. We first consider periods from 5 to 32, then the last 10 periods (from 23 to 32) and finally the last 5 (from 28 to 32). From these data we notice that the number of quality S permits and the efficiency of the market are of the same order of magnitude and are increasing when the price of the request for information decreases. That is to say when one passes from the treatment SUP to INF, the values of these two quantities increase. Our results closely approximate those of Cason et al. [6].

Table 2. The average number of S and I type water permits exchanged and the average efficiency of the market in relation to the period and treatment

	Number of permits exchanged						**Market efficiency**		
	REF		*SUP*		*INF*		*REF*	*SUP*	*INF*
	I	*S*	*I*	*S*	*I*	*S*			
The average per period and per treatment over the period from 5 to 32 (i.e. 28 periods outside the trial period)	7,6 (84)*	0,5 (84)	5,1 (56)	2 (56)	3,9 (84)	5.7 (84)	0,8 (84)	0,65 (56)	0,82 (84)
The average per period and per treatment over the period from 23 to 32 (i.e. 10 periods)	8,4 (30)	0,4 (30)	6,6 (20)	1,5 (20)	4 (30)	5,9 (30)	0,3 (30)	0,2 (20)	0,39 (30)
The average per period and per treatment over the period from 28 to 32 (i.e. 05 periods)	8,2 (15)	0,6 (15)	4,7 (10)	1,6 (10)	4,4 (15)	5,2 (15)	0,17 (15)	0,08 (10)	0,21 (15)

*( ) In parentheses; this is the total number of periods averaged over. For example, the REF treatment has 3 sessions (including 28 periods each), that is a total of 84 periods (28 * 3). Similarly, the SUP treatment has 2 sessions that is a total of 56 periods (28 * 2).

Source: The results of the auction for irrigation carried out in October 2018.

Table 3. The test for the presence of individual effects

Random-effects GLS regression	**Number of obs = 224**
Group variable (i): i	**Number of groups = 3**
R-sq: within = 0.9990	**Obs per group: min = 7**
between = 0.9977	**avg = 9.3**
overall = 0.9989	**max = 11**
Random effects u_i ~ Gaussian	**Wald chi2(8) = 79.06**
corr(u_i, X) = 0 (assumed)	**Prob> chi2 = 0.0000**

y	**|**	**Coef.**	**Std.Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
ref_1	|	0.1276908	0.004504	28.3	0.000	0.118863	0.1365186
ref_2	|	0.1273063	0.0126967	10.3	0.000	0.1024212	0.1521914
ref_3	|	0.1179305	0.0148751	7.93	0.000	0.0887758	0.1470852
sup_1	|	0.116193	0.0123626	9.40	0.000	0.0919627	0.1404232
sup_2	|	0.1382067	0.0148443	9.31	0.000	0.1091125	0.1673009
inf_1	|	0.1103578	0.0201584	5.47	0.000	0.070848	0.1498676
inf_2	|	0.1402051	0.0165104	8.49	0.000	0.1078452	0.1725649
inf_3	|	0.1277096	0.0197294	6.47	0.000	0.0890407	0.1663786
cons	|	-0.0013437	0.0019333	-0.70	0.487	-0.0051328	0.0024454
sigma_u | 0 **sigma_e | 0.00365688** **rho | 0 (fraction of variance due to u_i)**							

3.1. Presentation of the Basic Model

The results of the different auction experiments are considered to be panel data since they have two dimensions, one for groups of individuals and one for the period measured as time. These dimensions are respectively indicated by the indices i and t.

By using these data, we can exploit them in the search for information on the two sources of variation in statistical information such as temporal (where intra-individual variability) and individual (or inter-individual variability). Indeed, previous studies have shown that increasing the number of observations makes it possible, on the one hand, to ensure better precision of the estimators, and on the other hand to reduce the risks of multi-collinearity and above all to widen the field of investigation.

Before proceeding with the estimates, it is often necessary to verify the effect associated with each individual, i.e. an effect that does not change over time, but varies from one individual to another. There are two types of effects such as fixed and random.

In addition to identifying individual effects, the risk of correlation and heteroskedasticity in panel data is addressed.

In order to capture these effects, individual or temporal, we can add binary variables for each individual.

The first step requires verifying the presence of individual effects in our data. These effects are presented by an intercept specific to each individual, u_i.

We therefore proceed using a test for the presence of individual effects to test the null hypothesis (absence of individual effect) $H_0 : u_i = 0$ in the regression $Y_{it} = \alpha + X_{it}\beta + u_i + e_{it}$, $(e, u \sim \text{iid})$

The result is presented in Table 3. It clearly shows the rejection of the null hypothesis, and that our data do show individual effects (since the p-value = 0 <5%). So we have to *include individual effects in our model.*

3.2. The Random Effects Model

In order to capture these individual effects, we must assume the existence of dichotomous variables for each individual.

The next step is to choose the model that best lends itself to our data. A few previous studies have shown that fixed effects are more effective than random effects since they do not require structure from individual effects. On the other hand, they also showed that we lose N-1 degrees of freedom by modeling the individual effects in a fixed way, which generates an estimate of the coefficients of the explanatory variables inefficient.

We can therefore try to perform random modeling with individual effects.

However, and in order for the random effect estimators to be unbiased, their efficiency is based on a strong assumption that the errors (u_t) are not correlated with the explanatory variables. We therefore proceed to test the efficiency of the random effect estimator, by checking the correlation between errors and dependent variables and by using one of the most relevant tests (Hausman's test).

The Hausman test checks whether the estimators of the two fixed and random estimates are statistically different. The general idea is that both estimators are efficient under the null hypothesis that there is no relationship between the error terms and the explanatory variables, and thus the estimated parameters should change little. Hausman's test compares the variance-covariance matrix of the two estimators. The result of this test on our data used is presented in Tables 4 and 5, which follows a law χ^2 with 8 degrees of freedom. The p-value = 0.99>5%) is that we accept the null hypothesis of no correlation between the error terms and the independent variables. Then the introduction of the individual effects in the model allows having efficient estimations.

Indeed, it is desirable to take into consideration the random effects models which are unbiased.

Table 4. The fixed effects estimate

Fixed-effects (within) regression	**Number of obs = 224**
Group variable (i): i	**Number of groups = 3**
R-sq: within = 0.9990	**Obs per group: min = 7**
between = 0.9899	**avg = 9.3**
overall = 0.9989	**max = 11**
F(8,17) = 21.19	
corr(u_i, Xb) = -0.0533	**Prob> F = 0.0000**

y	**|**	**Coef.**	**Std. Err**	**t**	**P>|t|**	**[95% Conf. Interval]**	
ref_1	|	0.1275428	0.0046667	27.33	0.000	0.1176968	0.1373887
ref_2	|	0.125790	0.0146581	8.58	0.000	0.0948648	0.1567164
ref_3	|	0.1207552	0.016978	7.11	0.000	0.0849348	0.1565755
sup_1	|	0.1185561	0.0144191	8.22	0.000	0.0881345	0.1489777
sup_2	|	0.1354288	0.0163899	8.26	0.000	0.1008491	0.1700084
inf_1	|	0.1258632	0.025908	4.86	0.000	0.0712022	0.1805243
inf_2	|	0.1348662	0.0180691	7.46	0.000	0.0967436	0.1729887
inf_3	|	0.1161243	0.0226345	5.13	0.000	0.0683697	0.1638789
cons	|	-0.0010793	0.002095	-0.52	0.613	-0.0054995	0.0033408

sigma_u | 0.00147386
sigma_e | 0.00365688
rho | 0.13974028 (fraction of variance due to u_i)
F test that all u_i=0: F(2, 17) = 0.63 Prob> F = 0.5459

Table 5. The Hausman test

---- Coefficients ----					
	|	**(b)**	**(B)**	**(b-B)**	**sqrt(diag(V_b-V_B))**
	|	**fixe**		**Difference**	**S.E.**
ref_1	|	0.1275428	0.1276908	-0.000148	0.0012215
ref_2	|	0.1257906	0.1273063	-0.0015157	0.0073248
ref_3	|	0.1207552	0.1179305	0.0028247	0.0081842
sup_1	|	0.1185561	0.116193	0.0023631	0.0074213
sup_2	|	0.1354288	0.1382067	-0.002778	0.0069481
inf_1	|	0.1258632	0.1103578	0.0155055	0.0162745
inf_2	|	0.1348662	0.1402051	-0.0053389	0.0073417
inf_3	|	0.1161243	0.1277096	-0.0115853	0.0110937

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 1.20
Prob>chi2 = 0.9966

Table 6. Presentation of explanatory variables

Variables	**index**	**Description**
SUP	-	Indicator for SUP treatment
INF	-	Indicator for INF treatment
REF_ init	*1/t*	Variable which designates the effect of the initial periods of the reference treatment compared to the effect of the final periods of the REF treatment
SUP_init	*SECRET *1/t*	Variable which designates the effect of the initial periods of the SUP treatment compared to the REF treatment
SUP_fin	*SECRET *(t-1)/t*	Variable which designates the effect of the final periods of the SUP treatment compared to the REF treatment
INF_init	*ANNONCE *1/t*	Variable which designates the effect of the initial periods of the INF treatment compared to the REF treatment
INF_fin	*ANNONCE *(t-1)/t*	Variable which designates the effect of the final periods of the INF treatment compared to the REF treatment

Table 7. Total market efficiency

Periods	**5-32**		
Observations	**224**		
R ²	**0,92**		
Independent variables	**Estimated parameter**	**Standard deviation**	***p*-value**
Constant	0.0323766	0.0308531	0,294
Ref_init	0.2981002 ***	0.0448196	<0,0001
SUP_init	0.1306779	0.0890038	0.142
SUP_fin	0.125795	0.0887518	0,156
INF_init	0.1407282 **	0.0471819	0.003
INF_fin	0.1988139 ***	0.0478827	<0,0001

*: significant to à10%, ** : à5%, *** : 1%

3.3. Ordinary Least Square Linear Regression

3.3.1. Total Market Efficiency

Markets are therefore a phenomenon of convergence. Indeed, the results are different between the beginning and the end of each session. In particular, the regression would give us the possibility of studying the dynamics of the sessions, by introducing the effects of the start of the session and the end of the session in the manner of Noussair et al. [11].

Our experience contains three treatments: REF, SUP and INF. According to the analysis Noussair et al. [11] and Cason et al. [6], we then introduce two dichotomous variables to designate the treatment:

- SUP = 1 for the SUP treatment and 0 otherwise, and
- INF = 1 for INF processing and 0 otherwise.

This creation allows us to recreate the variables SUP_init, SUP_fin, INF_init and INF_fin, in order to have the effects captured at the beginning and at the end of the session.

The explanatory variables of the regression and their meanings are illustrated and presented in Table 6.

Similarly, the dependent variable is presented there as follows:

- EFFIC: the total efficiency of the market
- EFFIC_V: Profit for the efficiency of the seller's market, and
- EFFIC_A: Profit for the efficiency of the buyer's market.

The model is then presented as follows:

$$y = \beta_0 + \beta_1 * \text{REF\_ init} + \beta_2 * \text{SUP\_ init} + \beta_3 * \text{SUP\_ fin} + \beta_4 * \text{INF\_ init} + \beta_5 * \text{INF\_ fin} + u \qquad (1)$$

with u is the random error term.

The 1 / t terms handle the initial period's effect and the (t -1) / t terms handle the last period effect (long-term trends).

The linear regression of the ordinary least squares for the total efficiency of the market (EFFIC) is presented in Table 7.

The results clearly show that the markets do not react the same way at the start and at the end of the session.

The comparison of the variables Ref_init, SUP_init and INF_init with respectively Ref_fin, SUP_fin and INF_fin clearly shows the presence of convergence phenomena.

This can be explained by the learning of the players during each session.

The two variables which show good results and which validate the hypotheses formulated on the effect of the cost of information on quality are SUP_fin and INF_fin.

Indeed, the efficiency of the market is significant at 1% in the INF treatment than in the SUP and Ref treatment. In addition, the market efficiency in SUP processing presents estimators that are not significantly different from the market efficiency in Ref processing. In addition, these efficiency results clearly show that there is a threshold at which markets with information costs react as markets with total information asymmetry.

3.3.2. Market Efficiency for Buyers and Sellers

The question now is whether the type of agents (buyers or sellers) influences the efficiency of the market. To be able to answer, we make two additional independent estimates. One where we only take into account the gains generated by the sellers in the efficiency calculation (EFFIC_V) and the other where we only take into account the gains generated by the buyers (EFFIC_A).

The results of the ordinary least square linear regression are presented successively in Tables 8 and 9.

The results obtained clearly indicate that, for sellers and buyers, the results are practically the same as before except that the efficiency of the market in the SUP treatment becomes significant at 5% compared to the efficiency of the market in the Ref treatment.

3.4. The Logit Model and Logistic Regression

3.4.1. Logistic Regression of the Probability of Offering Superior Quality S for Sellers

In this session, we analyze the probability of delivering good quality for sellers based on the cost of information.

To do this, we must take into account an important term in our analysis which is the temporal autocorrelation of the residuals. In our case and since the decision-making of period N results from those of period (N-1), we must then add to our study an element called RATIO in the manner of Cason et al. [6] in order to move away from the temporal correlation of the residuals;

$$\text{RATIO} = \frac{\mathrm{E}\,(\pi_{\mathrm{S}}^{\mathrm{N}})}{\mathrm{E}\,(\pi_{\mathrm{I}}^{\mathrm{N}})} \tag{2}$$

This item is identified as the ratio of the expected earnings from selling Type S permits to the expected earnings from selling Type I permits.

Table 8. Market efficiency for buyers

Periods	**5-32**		
Observations	**224**		
R^2	**0,94**		
Independent variables	**Estimated parameter**	**Standard deviation**	***p*-value**
Constant	-0.0047065	0.0128428	0,714
Ref_init	0.3556128 ***	0.0275346	< 0,0001
SUP_init	0.0428815	0.0791287	0.588
SUP_fin	0.1987963**	0.0972721	0,023
INF_init	0.2180256 **	0.0876534	0.023
INF_fin	0,345 **	0.0884331	0,014

*: significant to à10%, ** : à5%, *** : 1%

Table 9. Market efficiency for sellers

Periods	**5-32**		
Observations	**224**		
R ²	**0,92**		
Independent variables	**Estimated parameter**	**Standard deviation**	***p*-value**
Constant	0.0190619	0.0158316	0,229
Ref_init	0.3677024 ***	0.0441244	< 0,0001
SUP_init	-0.0481102	0.1313898	0.714
SUP_fin	0.2937699 **	0.1366917	0,032
INF_init	0.1024169 **	0.0351025	0.004
INF_fin	0.2126876 ***	0.0394465	< 0,0001

*: significant to à10%, ** : à5%, *** : 1%

Table 10. Logistic regression of the probability of offering quality S for sellers

Periods	**5-32**		
Observations	**1120**		
LOG L	**-238.41**		
Independent variables	**Estimated parameter**	**Standard deviation**	***p*-value**
Constant	0.501831***	0.2548935	< 0,0001
Ref_init	14.540 ***	4.588	< 0,0001
SUP_init	-6.157	6.577	0.188
SUP_fin	0.847	0.770	0,830
INF_init	-15.542 **	5.032	0.033
INF_fin	2.615 *	1.201	0.073
RATIO	5.331 **	0.387	0.042

*: significant to à10%, ** : à5%, *** : 1%

Taking the following example: if a seller sold a few permits during the previous (N-1) periods and during period N he sells type I permits, then he updated his beliefs about the expected earnings by the following formula:

Expected gains for N from selling type I permits =

$$\frac{(\mathrm{N}-1)(\text{profits à N} - 1 \text{ d'avoir offert des I}) + \text{profits à N d'avoir offert des I}}{\mathrm{N}}$$

$$\text{So, } E\left(\pi_I^N\right) = \frac{(N-1)\pi_I^{N-1} + \pi_I^N}{N}$$

The model then looks like this:

$$y = \beta_0 + \beta_1 * \text{REF\_ init} + \beta_2 * \text{SUP\_ init} + \beta_3 * \text{SUP\_ fin} + \beta_4 * \text{INF\_ init} + \beta_5 * \text{INF\_ fin} + \beta_6 * \text{RATIO} + u \quad (3)$$

Remind that our goal is to study the probability of providing superior quality as a function of the cost of information using econometric analysis.

To do this, we create the dependent variable named QUALITY = 1 when the permit offered by the sellers has a higher quality and 0 when its quality is lower.

Indeed, we then perform a logistic regression (regression model for dependent variables taking dichotomous values) in the presence of random effects on individuals. Table 10 shows the estimate.

Note that the variables SUP_init and INF_init will not be considered, because they present the same results as previously. Only the final periods and therefore the variables SUP_fin, INF_fin and RATIO will be interpreted. The estimator of the variable RATIO is significant and positive, which confirms the law of theory. The greater the gain expected from selling type S permits, the more sellers tend to offer type S permits. Therefore the probability of offering type S permits is significant at 10% in the INF treatment than in the SUP and Ref treatments. However, the SUP and Ref treatments are not significantly different.

3.4.2. Logistic Regression of the Probability of Asking for Quality Information for Buyers

In this session, we study the treatments of the probability of asking for information on the quality of the permits, and therefore the INF (low cost) and SUP (high cost) treatments. The INF treatment is the reference of experience.

In addition, the permits from one period to the next are different, and therefore buyers do not have the ability to identify sellers from one period to the next.

We observe in Table 11 the distribution of the request for information on the quality of the permit throughout the experience in the INF and SUP treatments.

Table 11. Average number of information requests per period and per treatment

Period	INF treatment	SUP treatment
1-32	18.68	2.62
9-16	19.12	3.11
17-24	19	2
24-32	20.11	2.11

We clearly notice that the demand for quality information decreases with the cost of information. This means that the lower the cost, the greater the demand. It is strong in INF treatment (low cost treatment) compared to SUP treatment (high cost treatment) as verified by the model of Grossman et al. [12].

In addition, the determinants that influence the demand for purchasing permit quality information are the cost of the information and the price. Thus, the effect of the price of water permits is very variable and therefore the relationship between the demand for information and the price is not linear. For these reasons, we create the threshold variables to better distribute the prices:

- price_threshold1 is equal to the price if the price is less than 175 or greater than 350 and 0 otherwise;
- price_threshold2 is equal to the price if the price is between 175 and 200 and 0 otherwise;
- price_ threshold 3 is equal to the price if the price is between 200 and 280 and 0 otherwise;
- price_ threshold 4 is equal to the price if the price is between 280 and 350 and 0 otherwise.

We then perform a logistic regression with random effects on the individuals, and we define the dependent variable called DEM, equal to 1 if information has been requested on the permit considered and 0 otherwise. Table 12 shows the estimate.

Table 12. Logistic regression of the probability of requesting quality information

Periods	**5-32**		
Observations	**756**		
LOG L	**-385.15**		
Independent variables	**Estimated parameter**	**Standard deviation**	***p*-value**
Constant	-0.833 ***	1.248	< 0,0001
INF	4.477 ***	0.824	< 0,0001
SUP	1.548 ***	0.548	< 0,0001
prix_seuil 1	0.005	0.0026	0,932
prix_seuil 2	0.027 **	0.0065	0.001
prix_seuil 3	0.042 ***	0.0052	< 0,0001
prix_seuil 4	0.034 ***	0.0041	< 0,0001

*: significant to à10%, **: à5%, ***: 1%

The results show that the probability of requesting information is higher for INF and SUP treatments where the information is worth 15 and 50 points respectively compared to the Ref treatment such that the cost of information is infinite. It is significant at 1% for the two INF and SUP treatments.

The INF treatment differs by a more important and significant parameter at 1%. This affirms the law of demand which proves that the lower the cost, the higher the demand. Regarding the price, the higher it is, the higher the probability of asking for information. The **price_threshold1** variable (the price of which is less than 175 or greater than 350) has an insignificant coefficient and therefore it has no influence on the demand for information on the quality of permits, this confirms our hypothesis which says that 'below a certain price, buyers will not invest in purchasing the quality information since the gain from buying the permit always exceeds the gain at which no transaction was made and above 'a certain tariff the buyers do not purchase the information since they will not buy the permit even if it is of the higher type S.

Finally, the variables **price_threshold2, price_threshold3** and **price_threshold4** are positive and significant, which means that the demand for information does indeed depend on prices between 175 and 350.

We can therefore conclude that the demand for information does indeed depend on the price of the permit.

4. Conclusions and Discussion

We have shown in our analysis that small changes in the distribution of information can have a large and considerable impact on the economy.

Our study is motivated by the creation of a multi-round auction that deals with the problem of information manipulation, in order to see the behaviors and decisions of the bidders in the face of this manipulation and to search for the best strategy that leads the actors to achieve their goals by minimizing water consumption while increasing their earnings.

To achieve these objectives, we considered in a laboratory experiment, and we tested in the presence of treatments the impact of the unequal distribution of the cost of information on water quality between the different users (buyers and sellers) in order to measure on one hand the efficiency of markets for various users and the probability of asking for information on the quality and probability of offering higher quality water permits to sellers.

The results showed that the higher the information cost, the lower the number of high-quality permits sold, and thus the lower the efficiency of the market. Likewise, the more the cost of information increases, the fewer buyers will invest in purchasing the information.

Another conclusion that has been drawn is that any form of management that incorporates asymmetry of information will lead to an improvement in the distribution of the resource.

Thus, the strong responsiveness of the demand for information on the quality of the resource suggests that pricing policies can be a potential instrument for minimizing water consumption.

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