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Impact of institutional environment on irrigation practices : the case of a france area

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Abstract

The development of irrigation since the 1970s explains much of the disequilibrium observed in many territories between the water resources available and the quantity of anthropogenic water withdrawals. The aim of this paper is to analyze the impact of public policies (agro-environmental measures as part of agricultural policy and instruments for managing water demand as part of environmental policy) on irrigation decisions. The study area is the Charente-Maritime department of France, a territory with characteristics that appear to be particularly relevant to this research topic. First, irrigation decisions in 2003 and 2009 are evaluated using a sequential probit model. Second, an attempt is made to identify the determining factors of changes in irrigation intensity, and to estimate the effect of environmental policy instruments (irrigation restriction rulings, abstraction taxes, agro-environmental measures). To do so, a Heckman procedure is used to correct for double selection bias related to irrigation choices in 2003 and 2009. Whilst the successive CAP reforms have sought to reduce incentives for irrigation, such efforts still seem too limited compared to the benefits of irrigation for field crop farms. Furthermore, the results of estimates show that in this context only regulatory tools (restrictions on irrigation) have any significant effect on the limitation of irrigation.

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1. Introduction

The relationship between agriculture and water resources is governed by two political priorities: farming on the one hand and environment on the other. The use of environmental resources in farming is therefore not only impacted by the environmental policy rules, but also by agricultural policy (Common Agricultural Policy, or CAP), which also guides production and irrigation decisions by farmers and their relationship with the environment.

The CAP, introduced during the 1960s to support the implementation of changes in the agricultural productive system and attain the objective of securing sufficient food supplies at that time, shaped the productivist model (Allaire and Boyer 1995, Mollard 1995), based on the intensification and industrialization of farming in order to increase production and improve yields. While the initial objectives of the CAP were rapidly achieved (Butault *et al.* 2004), the incentives provided by the agricultural governance system resulted in extreme pressure on natural resources, especially water resources. The successive reforms of the CAP have sought to restrict incentives to irrigate, but such efforts still appear limited compared to the advantages afforded by irrigation for farmers producing field crops.

Several models have been developed to analyze how "farmers adjust rationally to the signals of a water shortage" (Moore *et al.* 1994). Some of these studies focus on demand for irrigation water (Bontemps et *al.* 2003, Schoengold *et al.* 2006), while others examine the effects on agricultural production of a decrease in the quantity of water allocated to farming (Moore and Negri 1992, Moore and Dinar 1995, Weinberg 2002).

This research follows on from the studies aiming to provide a better understanding of the determining factors of the cropping choices of farmers in terms of environmental resources. More precisely, the aim is to determine whether the measures in favor of the environment (agro-environmental measures (AEM) as part of agricultural policy and water management instruments as part of environmental policy) have any impact on the agricultural use of water.

The Charente-Maritime (CM) department on the west coast of France was chosen as the study area. Its characteristics appear to be particularly relevant to the topic of this study (Bouba-Olga *et al.* 2009). On the one hand, this department has experienced the biggest increase in irrigated areas in Europe. On the other hand, it contains a large number of productivist farms: field crops account for a large proportion of operations (over 65% of the utilized agricultural area), mostly growing irrigated maize (almost 80% of the irrigated areas declared under the CAP). Finally, farming is by far the biggest consumer of water, accounting for over 80%. The early years of this century were marked by recurrent, serious water shortages within the department, due to the substantial shortfall between the water resources available and anthropogenic needs. Changes in farming withdrawals thus appear to be essential in order to lower the quantitative pressure on resources. Additionally, a tougher coercive policy has been observed in the department over the last few years, with a downward trend in the surface areas under irrigation through to 2008 (a 24% decrease in the areas under irrigation between 2004 and 2008), followed by a much smaller increase in these areas than that observed on the national scale. Such changes in practice could therefore be considered as evidence that the action of central government in the department is effective.

An original database was used, recording all the information supplied in the CAP returns filed by farmers in CM in 2003 and 2009. Several indicators were constructed relating to environmental policy and agro-environmental policy. The role played by several variables in the evolution of farming practices was then tested. This research focuses on the growth rate of irrigation intensity between 2003 and 2009. This rate can only be measured for those farms using irrigation over the period concerned. To avoid any selection bias in the estimation of this rate, due account must be taken of the endogenous choice of farmers to irrigate or not. A dual regime model is therefore estimated with a double selection. The article is organized as follows. The context is presented in Section 2, i.e. the main changes in agricultural policy and water policy in France over the period covered by the database (2003-2009). Next, the data used are presented and the econometric processing is explained in Section 3. Finally, the results of the econometric processing are discussed in Section 4. Section 5 deals with conclusions and economic implications.

2. Context: a changing CAP and tougher water management policy

The institutional framework in which French agriculture has evolved is presented here, with an analysis of a few key aspects of agricultural and environmental policies. We attempt to observe how such determining factors can impact upon farming practices with respect to water resources in the study area.

2.1. Irrigation and the CAP

Historically the CAP's first-pillar aid has largely determined the economic situation of farmers (Ansaloni and Fouilleux 2006) and has had a significant impact on the orientation of productive systems (Colson *et al.* 1998). One of its consequences is the use of inputs (such as water) in quantities that are far greater than would have been the case without the CAP. As far as the system of aid allocation is concerned, the 2003-2009 period was a transitional period towards a system of decoupling,[1] whereby aid was linked to the agricultural surface area used in the past (i.e. per hectare on the basis of historical references). In 2009, there were no longer any direct incentives for irrigation, but there was an additional premium for irrigation and another premium for field crops. So the relationship between the maximization of production means (number of hectares and number of heads of livestock) and the maximization of aid was maintained. Since 1999, the aim of agro-environmental policy has been to encourage farmers to adopt or to pursue environmentally friendly practices through the payment of financial counterparties from the government on the basis of contractual commitments. Finally, at present this instrument is not particularly focused on the quantitative management of water resources.

2.2. Irrigation and the water management policy in France

Local management of water resources is based essentially on two instruments in CM: one incentive and the other coercive. The incentive instrument is associated with the withdrawal taxes levied by the water boards on farmers according to their use, in exchange for the payment of aid for investments to conserve water resources. The taxes paid to the water boards are often criticized for failing to observe the consumer-payer principle, given that the payments from the biggest consumers, in this case farmers, are not matched with their withdrawals of water resources. The coercive instrument is characterized by the rulings issued by local government in periods of critical shortage. Water withdrawals can be restricted or even forbidden in the public interest. If the thresholds established by the government are reached, the volume allocated is reduced in proportion to the severity of the shortage. Over the last few years, there has been a visible tightening of regulatory policy governing water resources. The quantitative objective – i.e. a balance between the resources available and the withdrawals by users in each basin – has resulted in the implementation of an annual decrease in the volumes authorized for agricultural withdrawal since 2006.

The successive reforms of the CAP have sought to limit the incentives for irrigation but such efforts still appear to be limited in comparison with the advantages afforded by irrigation for farmers producing field crops. In parallel, there has been a tightening of water resource management policy. This article seeks to determine whether the measures adopted in favor of the environment – AEM as part of agricultural policy and water resource management instruments as part of environmental policy – have any impact on the agricultural uses of water i.e. on the irrigation practices of farmers.

[1] "Coupled" aid received by farmers is linked to the nature and volume of production.

3. Methodological framework

3.1. The data

Table 1: Descriptive statistics of the model's explanatory variables

Variables	All farms in 2003 (n = 4 665)			Farms using irrigation in 2003 (n=1453)			Farms using irrigation in 2003 and 2009 (n=1190)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Moy
Growth rate of irrigation intensity between 2003 and 2009							-0.99	0.89	-0.21
Control variables									
UAA in hectares	1.02	672.60	67.54	1.55	672.60	105	2.66	672.60	112.20
Legal status of the farm									
Company	0	1	0.12	0	1	0.20	0	1	0.21
Sole proprietor, limited liability	0	1	0.88	0	1	0.80	0	1	0.79
Percentage of crops in the UAA in 2002 (Area/UAA)									
Maize	0	100	15.39	0	100	29.71	0	100	30.67
Small grains	0	100	30.28	0	100	27.33	0	100	26.66
Protein crops	0	90.06	1.32	0	47.53	2.01	0	47.53	2.21
Oil seed crops	0	100	16.19	0	66.31	10.69	0	52.50	10.21
Other crops	0	100	36.82	0	95.05	30.26	0	100	30.25
Percentage of irrigated areas in the UAA in 2003				0.89	100	34.08	2.41	100	35.95
Growth rate of the UAA between 2003 and 2009	-99.6	1824	3.74	-99.4	645.3	4.63	-86.9	645.30	9,31
Growth rate of the irrigated area between 2003 and 2009				-0.99	3.80	-0.29	-0.99	3.00	-0.14
Environmental policy									
Number of days of rationing in 2003									
None	0	1	0.05	0	1	0.10	0	1	0.11
69 or 74	0	1	0.37	0	1	0.31	0	1	0.31
88 or 90	0	1	0.15	0	1	0.14	0	1	0.14
95 or 98	0	1	0.31	0	1	0.30	0	1	0.30
109	0	1	0.11	0	1	0.11	0	1	0.15
Rate of taxes per ha in 2003				0	112.30	11.60	0	112.30	11.65
AEM in 2009: yes				0	1	0.10	0	1	0.11

An original database was used, recording all the information supplied in the individual CAP returns filed by farmers in 2003 and 2009. This database contains the characteristics of the farms as presented in Table 1. It includes the 4,665 CM farms that made a CAP return, i.e. close to 65% of farms within the department. According to the 2010 agricultural census, CM contained some 7,400 farms. Not all of them file a CAP return; only those entitled to aid under the CAP[2]. Of the 4,665 farms present in 2003, 1,453 were using irrigation, i.e. over 30% of the farms. Of these 1,453 farms, over 80% were still using irrigation in 2009. Finally, of the 1,190 farms using irrigation in 2003 and 2009, the irrigation intensity (percentage of areas under irrigation out of the total agricultural area of the farm) dropped by 21.1% over the period.

The data from these returns are completed by data on agro-environmental policy and environmental policy in the area, the objective being to estimate the impact of these elements on the behavior of farmers with respect to water resources. On the basis of the administrative orders from 2003 to 2009, a record was made of the rulings from the CM Prefect for the annual management of water resources, with a framework ruling drawn up prior to the start of

[2] Given the impossibility of cross-referencing this database with other returns databases, it should be noted that there is no information on the prices, costs or incomes of the farms.

an irrigation campaign and rationing orders issued during the campaign. Indicators were constructed to take account of the total number of days affected by the rationing orders in spring and summer, i.e. during the period when the irrigation need is greatest among farmers. Such information is obviously not perfect. Only a theoretical measure of the restriction on use is observed, rather than the real implementation of that measure, as this practice is unknown to the governmental departments collecting the data. Using the records of taxes paid to the water board, a variable was also constructed expressing the rate of taxes paid per hectare as applied to the farms. Finally, the farms having contracted an AEM were distinguished from the rest.

3.2 The econometric model

The aim of the model is to estimate the role played by the public policy instruments (amount of withdrawal taxes, number of days affected by rationing orders, and the contracting of a AEM) on the growth rate of the percentage of areas irrigated[3] by farmers between 2003 and 2009. The focus is therefore on farms which used irrigation in 2003 and in 2009. This sub-sample is obtained non-randomly among farmers. This selection can give rise to biases. To correct for any possible selection bias, the model has to estimate the probabilities of using irrigation in 2003, of continuing the use irrigation in 2009, and to see how the areas under irrigation change between the two periods, i.e. to focus on the growth rate of the areas under irrigation. We can have another selection bias. As we said above, only farmers those entitled to aid from the CAP file CAP return. So, small farms or farms not using irrigation are not in the database. But, all the farms using irrigation for field crops make a return, hence the interest of using this database. Given that we observe almost all farms using irrigation we possibly over-estimate the probability of irrigating in 2003. Unfortunately we can not correct this bias because we do not have information on farmers who have not make a CAP return. But the probability of irrigating in 2009 and the growth rate of the irrigated agricultural area should not be impacted because farmers who did not use irrigation in 2003 did not start irrigating in 2009. To simplify the model notations, the farm index has been omitted.

Let us consider variable $I_{03} = I\{I_{03}^* = X_{03}\beta_{03} + u_{03} \geq 0\}$. I_{03} characterises the fact that the farm uses irrigation in 2003. We consider another variable $I_{09} = I\{I_{09}^* = X_{09}\beta_{09} + u_{09} \geq 0\}$. I_{09} characterises the fact that the farm uses irrigation in 2009 given that it was using irrigation in 2003. If the farmer uses irrigation in 2003 and 2009, we observe the growth rate of irrigation intensity over the period 2003-2009 which is between]-1 ; 1[. To guarantee that the predictions fall within that interval, the growth rate was transformed using the reciprocal function of the hyperbolic tangent. So, the explained variable, y is defined by:

$$y = 0{,}5 \ln\left(\frac{1+TC}{1-TC}\right) = X_{ir}\beta_{ir} + u_{ir}$$

TC characterises the growth rate of the area under irrigation for the farm. X_j $(j = 03{,}09, ir)$ are the vectors of characteristics of the farm, β_j $(j = 03{,}09, ir)$, are the vectors of associated parameters and u_j $(j = 03{,}09, ir)$ the measurement errors associated with the three relationships. These three errors are assumed to be distributed by a standard normal trivariate:

$$\begin{pmatrix} u_{03} \\ u_{09} \\ u_{ir} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{03,09} & \rho_{03,ir} \\ \rho_{03,09} & 1 & \rho_{09,ir} \\ \rho_{03,ir} & \rho_{09,ir} & \sigma_{ir}^2 \end{pmatrix}\right]$$

We estimate a two steps switching modeling with double selection. The first step estimates the probability of using irrigation in 2003 and of continuing to use irrigation in 2009. A model with selection is used (Van de Ven and Van Praag 1981, for the bivariate probit model with

[3] The growth rate of the percentage of areas under irrigation is defined by the following relationship: percentage of areas under irrigation in 2009 minus the percentage of areas under irrigation in 2003 divided by the areas under irrigation in 2003.

selection, Tunali 1986, for the dual regime model with double selection or Garcia *et al.* 2009, for an application). The three contributions to the likelihood are given by:

- $P_1 = \mathrm{P}(I_{03} = 0 | X_{03}) = 1 - \Phi(X_{03}\beta_{03})$: contribution of a farm not using irrigation in 2003,
- $P_2 = \mathrm{P}(I_{03} = 1, I_{09} = 0 \mid X_{03}, X_{09}) = \Phi(X_{03}\beta_{03}) - \Phi_2(X_{03}\beta_{03}, X_{09}\beta_{09}, \rho_{03,09})$: contribution of a farm using irrigation in 2003 but not in 2009,
- $P_3 = \mathrm{P}(I_{03} = 1, I_{09} = 1 \mid X_{03}, X_{09}) = \Phi_2(X_{03}\beta_{03}, X_{09}\beta_{09}, \rho_{03,09})$: contribution of a farm using irrigation in 2003 and in 2009.

$\Phi(.)$ and $\Phi_2(.,.,\rho)$ characterise respectively the distribution function of a standard normal distribution and a standard normal bivariate distribution with a correlation coefficient of ρ.

The second step estimates the growth rate of the irrigated agricultural area, observed only for farms using irrigation in 2003 and in 2009. The problem of selection can be corrected by a two-step estimation procedure of the Heckman correction type (Heckman 1979, Maddala 1983), This correction (see for example Garcia *et al.* 2009 or Henning and Henningsen 2007) must take into account the following conditional expectation:

$$y | I_{03}^* \geq 0, I_{09}^* \geq 0, X_{ir} = \mathrm{E}(y | I_{03}^* \geq 0, I_{09}^* \geq 0, X_{ir}) + v = X_{ir}\beta_{ir} + \rho_{03,ir}\lambda_{03} + \rho_{09,ir}\lambda_{09} + v$$

with $\lambda_{03} = \dfrac{\phi(X_{03}\beta_{03})\Phi\left(\frac{X_{09}\beta_{09} - \rho_{03,09}X_{03}\beta_{03}}{\sqrt{1-\rho_{03,09}^2}}\right)}{\Phi_2(X_{03}\beta_{03}, X_{09}\beta_{09}, \rho_{03,09})}$ and $\lambda_{09} = \dfrac{\phi(X_{09}\beta_{93})\Phi\left(\frac{X_{03}\beta_{03} - \rho_{03,09}X_{09}\beta_{09}}{\sqrt{1-\rho_{03,09}^2}}\right)}{\Phi_2(X_{03}\beta_{03}, X_{09}\beta_{09}, \rho_{03,09})}$ (1)

The standard deviations have been corrected (see for example Henning and Henningsen 2007, for the form of the covariance variance matrix).

To explain the probability of irrigating in 2003, three control variables (X_{03}) are used:

- the farming area in 2003 (Utilized Agricultural Area – UAA) enabling the measurement of any size effect on the behavior of the farmer;
- the legal status of the farm in 2003 (sole proprietorship and limited liability farms / agricultural firms, including agricultural joint ventures);
- the percentage of crops in the UAA. Five types of crop systems were considered: maize, small grains, oilseed crops, protein crops, and others crops (meadows, orchards, vineyard…). To avoid any endogenous bias, the crops produced the previous year, i.e. in 2002, were used. These variables made it possible to observe whether there were any inertia effects in irrigation practices.

To explain the probability of continuing with irrigation in 2009 (X_{09}) and the growth rate of the percentage of areas under irrigation (X_{ir}), several sets of variables were considered[4]:

- the control variables used to explain the probability of irrigation in 2003;
- three additional control variables: i) the percentage of areas under irrigation in the UAA in 2003. The aim was to test for the weight of the past in farming behavior, and more specifically the existence of an inertia phenomenon, ii) to test for a nonlinear effect of this variable, the square was added, iii) the rate of growth of the UAA between 2003 and 2009. This variable is used to test for the role played by agricultural concentration and its impact on irrigation behavior,
- three variables of environment policy instruments: i) the number of days of rationing in 2003. The rulings of one year have no impact on the decision to stop irrigation or not in that year, because the planting and irrigation plan had already started when the first rulings were implemented. However, the rulings of a given year can impact on decisions for the coming years as regards irrigation (a farmer who stopped irrigating one year does not restart irrigation the following years). This information could have an impact on the intensity of irrigation. Although this variable is theoretically continuous, a finite number of

[4]The amount of the subsidies collected by farmers has not been used in the model as it was strongly correlated with the total surface area of the farm.

days of rationing can be observed. It was therefore decided to introduce it discretely using 5 dummy variables: no rationing day, 69 or 74, 88 or 90, 95 or 98 and 106, ii) the rate of taxes per hectare in 2003 (amount of taxes/irrigated areas), tested only on the population of those using irrigation in 2003 (all subject to the tax system), iii) the contracting of a AEM. This variable appears as a proxy of the environmental awareness of farmers and a negative effect on their behavior can be expected.

Given that we have at least one nonoverlapping variable between X_{03} and X_{09} the vector of parameters, β_{03} and β_{09} can be identified (Maddala 1983, p.280). Theoretically speaking, there is no problem of identification concerning the equation measuring the growth rate of the irrigated agricultural area. Given the normal distribution assumption, we have a nonlinearity between the coefficients of the selection equations, the coefficients of the interest equation and the function λ in (1). For more robust results, another way of improving identification is to include exclusion restrictions. Manning *et al.* 1987, or Leung and Yu 1996, show that estimators are more stable when the set of variables for the equations are different (*i.e.* $X_r \neq X_{03}$ and $X_r \neq X_{09}$). In practice it is sometimes difficult to find exclusion restrictions. In this model we used all available variables and the inequality is verified only for the first relation. As a result, for the last equation the identification of the parameters partly relies on functional form assumption (Holm and Jaeger 2011).

4. Results and discussions

The results of the estimates are given in Table 2 (all things being equal). The coefficient of correlation between the two error terms associated with the probabilities of irrigation in 2003 and 2009 is negative and significant. So, the control variables not introduced into the model would have an opposite effect on the probabilities of irrigating in 2003 and of continuing to irrigate. One of the coefficients associated with the two selection bias correction terms (that associated with the probability of continuing to use irrigation in 2009) is significant. Failure to take account of the selection would have given biased estimators.

4.1. Control variables

The legal status of the farm does not play any significant role in the irrigation behavior of farmers. The fact of being a company rather than a limited liability firm or a sole proprietorship has no significant impact on the probability of using irrigation or on the irrigation behavior dynamics.

The UAA has a positive and very significant effect in the three equations. This finding confirms the existence of a size effect on irrigation behavior. The UAA positively impacts on the probability of using irrigation in 2003 but also the probability of continuing to use irrigation in 2009. The size effect also impacts on the irrigation behavior dynamics. These results confirm the positive role of farm concentration on irrigation behavior.

As far as the probability of using irrigation in 2003 is concerned, the variables describing cropping practices are highly significant and associated with a negative coefficient. Maize is the crop that requires the most water in summer. It is not therefore surprising to see that, the higher the percentage of maize in the UAA, the greater the probability of using irrigation in 2003. Conversely, the greater the percentage of small grains, oil seed and protein crops or other crops (vineyard, meadows, orchards) in the UAA compared to that of maize, the lower the probability of using irrigation in 2003.

Regarding the probability of continuing to use irrigation or not, there is no crop rotation effect except for the modality relating to other crops which is associated with a positive coefficient. Two arguments can be put forward to explain these findings: i) the area planted with vines, which by definition is not irrigated, provides irrigating farms with the financial cushion to continue to irrigate; ii) here it would be possible to measure, at least partially, an effect linked to the decoupling of aid which came into effect in 2006.

The growth rate of irrigation intensity increases with the percentage of maize in the UAA. Farms with a focus on maize therefore quite logically tend to irrigate but also tend to increase their irrigation intensity (reinforcement of the status of irrigation on the farm).
The coefficient associated with the percentage of irrigated areas in the UAA for each farm using irrigation in 2003 is positive and significant only for the probability of continuing to irrigate. Hence the higher the percentage of areas under irrigation in the UAA in 2003, in other words the greater the irrigation intensity in 2003, the higher the probability that the farm will still use irrigation in 2009. This again shows the effect of a certain behavioral inertia. The coefficients associated with the square of this variable are also significant and negative. This demonstrates a nonlinear concave effect of the percentage of areas under irrigation both on the probability of continuing to use irrigation and on the evolution of irrigation intensity. Note that, all else being equal, the probability of continuing to irrigate rises for portions of less than 45% of areas under irrigation, and decreases above this level.
The growth rate of irrigation intensity increases as long as the percentage of irrigation is less than 30%,[5] and decreases beyond that figure. This evidences a tendency to maintain irrigation, as the farmer seeks to take advantage of higher market prices and to limit his exposure to climatic risks, with, however, a drop in irrigation intensity. This could be explained by the changes in government policies and perhaps by the increase in the "green awareness" of farmers, but also by the organizational constraints involved in using irrigation on the farm.
The coefficient associated with the growth rate of the UAA between 2003 and 2009 has a highly significant positive effect only on the probability of continuing to use irrigation. The variation in the UAA over the period has no effect on the variation in irrigation intensity. Hence an increase in the UAA increased the probability of irrigation being maintained on the farm in 2009, but has no effect on the variation in irrigation intensity. When this finding is compared to the one concerning the UAA, it can be concluded that large farms in 2003 were more likely to continue using irrigation in 2009 and to bolster the presence of irrigation over the period (an increase in irrigation intensity). Any increase in farm size has a positive impact on maintaining irrigation on the farm, although without any effect on the variation in irrigation intensity.

4.2. Environmental variables

The first variable related to quantitative water management instruments refers to coercive management of the resource. There is an observed effect of the number of days of rationing during the irrigation period on the types of irrigation behavior.
The number of days of rationing does not have the same effect on the probability of continuing to irrigate and on the growth rate of irrigation intensity. Only those farms where the number of days of rationing is more than 100 days are likely to irrigate less. Consequently, the substantial restrictions imposed on farms in a given year can impact on the irrigation decisions of farmers over the years to come. However, the number of days of rationing has a negative impact on the variation in irrigation intensity. In other words, in certain cases, this regulatory instrument may influence the decision to "stop or not stop irrigation" and does influence the decision "to increase or not increase the status of irrigation on the farm". Irrigation is associated with relatively substantial financial constraints (amortization of capital expenditure) and technical constraints (installation and maintenance of equipment). The decision to entirely stop irrigation may not be optimal or profitable for the farmer. The farmer may continue irrigating but modify his irrigation technology (Zilberman *et al.* 2003) and/or his cropping system (Amigues *et al.* 2006).

Table 2: Results of the estimate of the probabilities of irrigation and irrigation intensity

[5] These percentages were calculated on the basis of the estimated parameters. They characterize the maximum value of the quadratic function used to introduce the percentage of areas under irrigation into the equations of the model.

Variables	Probability of irrigation in 2003		Probability of continuing to use irrigation in 2009		Growth rate of irrigation intensity
	Coeff	*ME*	*Coeff*	*ME*	*Coeff*
Constant	1.633*** (0.100)		-0.343 (0.371)		0.1334 (0.1343)
Utilised Agricultural Area	0.012*** (0.000)	0,0025** (0.001)	0.003** (0.001)	0.0015** (0.0007)	0.0004** (0.0002)
Legal status of the farm: Sole proprietor and limited liability (ref.)					
Company	-0.044 (0.073)	-0.0133 (0.054)	-0.001 (0.116)	-0.0008 (0.001)	0.0000 (0.0275)
Percentage of crops in the UAA in 2002: Maize (ref.)					
Small grains	-0.032*** (0.001)	-0.0072** (0.003)	0.002 (0.004)	0.0002 (0.032)	-0.0069*** (0.0015)
Oil seed crops	-0.043*** (0.002)	-0.0097** (0.005)	0.005 (0.006)	0.0009 (0.0006)	-0.0049*** (0.0024)
Protein crops	-0.012*** (0.005)	-0.0027*** (0.001)	0.014 (0.009)	0.0033 (0.002)	-0.0062*** (0.0025)
Other crops	-0.038*** (0.001)	-0.0086** (0.004)	0.012*** (0.005)	0.0027*** (0.006)	-0.0014 (0.0019)
Percentage of areas under irrigation in 2003			0.063*** (0.008)	0.0107*** (0.003)	0.0041 (0.0033)
Percentage of areas under irrigation in 2003 squared			-0.059*** (0.009)		-0.0078** (0.0036)
Growth rate of the UAA			0.014*** (0.002)	0.0031** (0.0015)	-0.0005 (0.0004)
Number of days of rationing in 2003: None (Ref.)					
69 or 74			-0.153 (0.167)	-0.0452 (0.035)	-0.1766*** (0.0399)
88 or 90			-0.222 (0.183)	0.0508 (0.032)	-0.1846*** (0.0463)
95 or 98			-.0.222 (0.169)	-0.0530 (0.033)	-0.1935*** (0.0444)
109			-0.311* (0.178)	-0.0730* (0.04)	-0.1735** (0.0496)
Rate of taxes per hectare			0.004 (0.004)	0.0011 (0.001)	-0.0013 (0.0015)
Agro-environmental measure			0.135 (0.155)	0.0358 (0.025)	-0.0328 (0.0376)
$\rho_{03,09}$			-0.767*** (0.101)		
$\rho_{03,ir}$ (λ_{03})					-0.1199 (0.0766)
$\rho_{09,ir}$ (λ_{09})					0.5622*** (0.1113)
Pseudo-R^2	0.30				
Percent agreement	88.5		85.3		
R^2					0.27

Notes: the parameter if significant at *: 10%; **: 5% and ***: 1%. Authors' calculations. ME : Marginal Effect

The tax rate, an instrument used to encourage water management, has no statistically significant effect on the probability of continuing to use irrigation in 2009 or on the variation in irrigation intensity. This result can easily be explained. The withdrawal taxes raise problems of fairness between consumers, since farmers pay only a very small percentage of the total dues compared to other users (private individuals in particular). They also encourage people to save water, given the low level of taxes on farmers. It has been shown that the incentive effect emerges at a rate above 9 eurocents/m^3 (Montginoul 1997). In CM, the rate applied by the two water boards is less than 1 eurocent/m^3. Therefore, the taxes are simply fiscal revenues ensuring the budgetary balance of the water boards. This explains why the "taxes" instrument as applied in CM has no noticeable effect on irrigation behavior dynamics.

This finding is perhaps specific to the region and/or to the fact that all types of crops are considered. More generally speaking, agricultural economics specialists seem to agree that farmers are not paying "the fair price" for water (their price is less than €0.1 per cubic meter compared to €3 on average for households).
The coefficients associated with the undertaking to observe an AEM are not significant. This finding suggests that the farmers who contracted an AEM in 2009 are no more likely to abandon irrigation practices on their farm than the others, thus confirming the notion that AEMs are above all implemented on a farm for economic reasons.
All in all, government interventions in quantitative water management have produced mixed results. Only the "withdrawal restriction ruling" measure has a statistically significant effect on the irrigational behavior of the farmers. The price-based water management instruments (withdrawal taxes) or those that depend more on a proactive approach (AEM) do not appear to have any effect on the change in farming behavior with respect to irrigation. The fact that the majority of farmers in CM have a productivist rationale, coupled with the differential in aid per hectare (extra premium for irrigation), is an obstacle to any decrease in water withdrawals. Therefore, the economic opportunities and advantages of irrigation for this type of farm are such that farmers agree to reduce their areas under irrigation only when they are forced to do so, that is, when coercive instruments such as restriction orders are implemented.

5. Conclusion

The statistical processing carried out provides an analysis of the determining factors in changes to irrigation practices in CM. The econometric modeling used for farms in CM between 2003 and 2009 fails to show any effect of government policies (AEM and instruments for the management of water demand), with the exception of rationing. The absence of any effect related to AEMs could be linked to the low level of constraints applied by the contracts involved in such measures for quantitative water management, but also to a poor approximation of the information gathered. The fact that the economic instrument (water taxes) has no impact could be related to the level of those taxes, which would appear to be insufficient to have any impact on crop irrigation.
These contrasting results raise the question of modifying and/or boosting quantitative water management in CM. Should the coercive instruments be reinforced or should the parties concerned be encouraged to modify their practices (incentive instruments, proactive approaches, etc.)? The answer to that question is partly constrained by the changes in agricultural policy. Indeed, despite the fact that environmental issues are increasingly being integrated into productive farming processes, when irrigation supports the intensification of farming, market opportunities stemming from rising agricultural prices call into question the relevance of incentive instruments to change irrigation practices.
It is regrettable, however, that a number of variables were not available, in particular economic variables such as the mean prices of crops or production costs. The former data would have made it possible to work directly from a panel model on the areas under irrigation, with correction of the selection bias. The latter would perhaps have afforded more in-depth understanding of the productive choices of farmers. Lastly, this work could be enriched by an analysis of the latest CAP reforms so as to observe whether these changes alter this paper's findings on the determining factors that influence the change in farming behavior with respect to water resources.

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