The impact of the institutional environment on irrigation practices: Econometric analysis based on farming in Charente-Maritime, France

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Abstract

This paper examines the combined effects of agricultural and environmental policies. 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 traces in water withdrawals. The management of water resources must take into account the policies affecting farming practices, agricultural policy on the one hand, and environmental policy on the other. Despite a process of better integration of environmental issues into agricultural production, certain areas of agricultural policy (in certain contexts of production) result in the continued exertion of pressure on water resources. It is in light of this that we propose here to analyse the issue of whether or not measures in favour of the environment (agri-environmental regulation within the agricultural policy and instruments for managing water demand within the environmental policy) have an effect on the evolution of agricultural practices with respect to water resources. To do this, we chose the Charente-Maritime department (region of Poitou-Charentes, France) as the land area of study, a territory whose characteristics seem to us particularly relevant to our research topic.

Keywords: Charente-Maritime, water resources, environmental policy, irrigation, switching model

1. Introduction

The relationship between agriculture and water resources is situated at the crossroads of two major domains of public action: agriculture on the one hand, and the environment on the other. Farmers' behaviour with respect to environmental resources is therefore not only affected by the rules laid down by the State (or by Europe) in the framework of environmental policy. Agriculture sector policy (the Common Agricultural Policy (CAP)) also structures and orients farmers' strategies, and thus their relationship to the environment. By taking into account all such institutional variables, we are able as well to highlight potentially blocking

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elements that can diminish the efficiency of water resource management in a given territory. Therefore, the question raised here is clearly the issue of coherence between public policies, notably the environmental and sector-based policies.

This research is in keeping with many previous studies that aim to better understand the determinants of farmers' behaviour with respect to environmental resources. Several models have been developed to study the impact of the CAP on land allocation decisions (for example, MAGALI, MEGAAG, PMP INRA). Buisson (2008) focuses on the effects of the decoupling of EU payments on irrigation practices, distinguishing between partial and total decoupling scenarios. Other studies have observed observe how "producers adapt rationally to water-scarcity signals" (Moore *et al.*, 1994). In this context, some articles study agricultural water demand (we can mention Moore *et al*. (1994), Bontemps and Couture (2002) and Schoengold *et al*. (2006)) while others analyse the effects of water-supply reductions on agricultural production (we can mention Moore and Negri (1992), Moore and Dinar (1995) and Weinberg (2002)). In this study, we adopt an original approach. Firstly, we demonstrate that, in our case study, incentives from the CAP work toward maintaining quantitative pressures exerted on water resources. By taking this context into account, we propose in the second part to carry out econometric investigations for the purpose of estimating the effect of measures in favour of the environment (agri-environmental regulation within the agricultural policy and instruments for managing water demand within the environmental policy) on farming practices with respect to water resources. The existence of contradictions between agricultural policy and environmental policy is highlighted. Therefore the question raised here is clearly the issue of the combined effects of the two public policies.

The territory we chose to study is the Charente-Maritime department situated on the west coast of France (Poitou-Charentes region). The characteristics of this territory do indeed seem particularly suited to the object of our research (Bouba-Olga *et al*., 2009). This department is located in the region that has witnessed the greatest increase in irrigated land area in France, whilst France itself has had the most rapid growth of irrigated land use in Europe. Charente-Maritime is characterised by the strong presence of irrigated agriculture, since more than one in four farm holdings irrigate. Agricultural activity has by far the most significant impact on the water resource (more than 80 % of water withdrawals in net value). Tourism activities (the second most visited department in France) and shellfish farming (the most productive shellfish centre in Europe) are leading economic activities in Charente-Maritime and both depend on water resources during the summer, precisely when agricultural withdrawals are at their highest. During the 2000s, several serious quantitative crises can be explained by the disequilibrium between the water resources available and the number of anthropogenic needs. Therefore, it is clear that water resource management is affected by the evolution of agricultural water withdrawals. Over the past few years, a hardening of the regulatory policy in Charente-Maritime and a tendency of reducing irrigated land areas can be observed (diminution by 24 % between 2004 and 2008), suggesting that State intervention is efficient. In the aggregate, the characteristics of our land area of study seem to us particularly relevant to our research topic.

We exploit an original database covering the various information furnished in CAP subsidy claims by farm holdings in the Charente-Maritime department for the years 2003, 2006 and 2009. We construct a few indicators that pertain to environmental policy and to agri-environmental policy. We go on to test the role of several variables in the evolution of farming practices in the region, using a double-selection switching model: our first equation estimates the probability of irrigating in 2003 for the whole set of farm holdings in the Poitou-Charentes region; the second equation explains, within the population of farming operations that did irrigate in 2003, the probability of continuing to irrigate in 2009; and finally, the third equation represents, for the farm holdings that continued to irrigate in 2009, the impact of different variables relating to the institutional environment on the growth rate of irrigation intensity between 2003 and 2009.

This article is organised in the following manner. We begin by presenting the major evolutions of agricultural and environmental policies in France during the years covered in our database (2003-2009). We then present the assembled data and describe the econometric methods employed. Finally, we discuss the results of our econometric analysis relating to the effect of measures in favour of the environment (agri-environmental policy and environmental policy) on the evolution of irrigation practices in the Charente-Maritime department.

2. The impact of agricultural and environmental policies on water resources in France

First of all, we present the institutional framework within which French agriculture evolves through an analysis of a few salient elements of agricultural and environmental policies. We endeavour to observe in what way these determinants can impact farmers' behaviour with respect to water resources in the territory under study.

2.1. The structuring role of first Pillar subsidies (market interventions and income support)

The CAP was established during the 1960s for the purpose of supporting the realisation of modifications in the agricultural productive system necessary to reach the objective assigned at that time to farmers of ensuring food supply security. Thus, this policy was to trace the outline the productivist model (Allaire and Boyer, 1995; Mollard, 1995), based on the intensification and industrialisation of agriculture, with the aim of increasing production and improving crop yields. While the initial objectives of the CAP were rapidly attained (Butault *et al*., 2004), the incentives emanating at the time from this system of agricultural governance took the form, on the environmental plane, of strong pressures exerted on natural resources and notably on water resources. Indeed, during the 1960s, environmental issues were hardly acute and environmental resources were in good state, hence the authorities' encouragement to profit from natural resources to increase agricultural productivity. As far as water resources go, CAP support, relayed by regional policies, explains the substantial development of investment in irrigation equipment, which not only made possible more secure, diversified and increased agricultural production, but also broadened cultivation possibilities. French irrigated land area has been multiplied by more than 3.5 between 1965 and 1995, and the percentage of irrigated farm holdings has risen from 8.4% to 14.5%. The Poitou-Charentes region has undergone the greatest increase in irrigated land area in France (while France itself has had the most rapid growth of irrigated land surface in Europe): the irrigated regional land area has been increased tenfold in thirty years (Boulanger, 2006). The volume of water withdrawals by farmers has been multiplied by a factor of 20 between 1970 and 1996.

While the successive reforms of the support system of the CAP's first Pillar since 1992 refer unambiguously to increased consideration of the environment, certain components of the agricultural governance system still represent incentives (both direct and indirect) for the maintenance and even the development of irrigation in farm holdings over the period of our study (2003-2009). First important element: even though we observe increased expenditure devoted to the second Pillar (rural development), the first Pillar (market interventions and income support) still represents today the largest financial envelope of agricultural policy, 80% of CAP spending. Secondly, since they determine farmers' economic situation to a great extent (Ansaloni and Fouilleux, 2006), the modalities of support attribution in the first Pillar continue to have a strong impact on the orientation of productive systems (Colson *et al*., 1998). This is why Chatelier *et al*. (2003) specify that it is "the current orientation of CAP financial incentives received by farmers that constitutes the most powerful lever in the agriculture-environment relationship" *(our translation)*. As far as what concerns the modality of attributing aids, 2003-2009 is a transition period toward a system of uncoupled aids (aids linked to farm holdings on the basis of historical references). However, there still exist in France, in 2009, additional irrigation premiums, additional field crop premiums, stigmata of the still-existing relationship between maximisation of the means of production (hectares, animal head count) and maximisation of subsidies[1]. Third important element: while the conditionality of aids linked to certain environmental constraints unambiguously reflects that environmental issues in the framework of productive agricultural activity have been taken into account, the constraints are still essentially based on national regulation (minimal norms)[2], which limits the potential impact of the CAP on the evolution of agricultural practices in the direction of the environment.

2.2. Liberalisation of the agricultural sector

The current context of agricultural sector liberalisation also influences farm operators' strategic behaviour (Mollard *et al*., 2003), and thus in an indirect manner, their interaction with the environment and water resources. The reestablishment of the link between farmers and market prices makes productive strategies much more sensitive to price evolutions. Precisely, we observe over the last several years a tendency of rising agricultural prices,

[1] The process of reforming subsidies in the first Pillar of the CAP was not achieved in 2009. One may, for example, note an important fact: the disappearance since 2010 of additional premiums for irrigation and for field crops. It is moreover question with CAP 2013 to abandon historical references as a basis of aid attribution (CER, 2010). Such references have the effect of maintaining an advantage for intensive and/or irrigated farming insofar as the amount of aid granted is higher than that of the other farming operations.

[2] Good practice guidelines exist, notably in the field of irrigation related to the French Law of 2006.

which may be explained, on the one hand by the increasing demand from emerging countries, conjugated with a non-increasing agricultural land area, and on the other by speculative phenomena, the later also having the effect of increasing price volatility (soaring prices in 2007 and collapse in 2009[3]). Market constraints provoke a reduction in farmers' room for manoeuvre, still more so for producers of standardised intermediate goods, encouraging them to continue the use of intensive techniques on their farm holdings for the purpose of ensuring the production level. Farmers then seek to reduce their operating costs and to benefit from increasing returns to scale through a simplification of tasks (by eliminating breeding for example and a reduction in the number of crops), an increase in plot and holding size, and a greater recourse to mechanisation. In this context, irrigation remains primordial for the productive organisation because it guarantees crop yields both quantitatively and qualitatively[4].

The Charente-Maritime department is characterised by the strong presence of productivist farming operations due to the weight of the land area in field crops (more than 65% of the total cultivated area) and more particularly in the production of irrigated maize (practically 80% of irrigated surface areas declared to the CAP in the department are in maize). Due to the characteristics of the farming operations in place, market constraints contribute to the perpetuation of intensive systems. More especially as they relate to water resources, incentives arising from the liberalisation of the agricultural sector in this territory therefore work to counter purpose of the instruments created to better protect the resource. Environmental regulation concerning water resources are thus assimilated by farmers to supplementary constraints imposed on productive systems, to an increase in production costs that complicate attainment of the economic objects and to a decrease in their revenue (Brun, 2003; Brun *et al*., 2006)[5].

2.3. Development of agri-environmental policy (second Pillar)

Environmental preoccupations were not truly integrated into the CAP until 1985. The object of agri-environmental policy is to incite farmers to adopt or to perpetuate methods that are respectful to the environment, in response to payments of a financial compensation by the public authority on the basis of contractual agreements (amount paid for the purpose of compensating the loss of revenue or additional costs that the methods represent for the farmer). In 1999, implementation by Member States of this policy became obligatory in the framework of the second CAP Pillar. The first agri-environmental contract, the Territorial Exploitation Contract (CTE, *Contrat Territorial d'Exploitation*), is to be replaced by the

[3] Prices then rose rapidly in 2010.

[4] Irrigation also concerns crops not requiring irrigation but are constrained by markets that impose production and quality regularity, which explains recourse to irrigation.

[5] It is important to make clear that the implementation of production modes that are more respectful of the environment can admittedly increase certain production costs or also provoke a reduction of production, but it may also coincide in some cases with input economies and with greater added value, hence a preservation, even an increase in agricultural revenue (Ansaloni and Fouilleux, 2006).

Sustainable Agriculture Contract (CAD, *Contrat d'Agriculture Durable*) which, although it retains numerous traits in common with the previous plan, makes it possible to target high-priority environmental risks, to simplify procedure and to provide improved budgetary controls (Thoyer and Saïd, 2007). Since 2007, there have been nine different agri-environmental measures (AEM): two national systems, six systems with national specifications but to be applied on the regional level and one system of territorialized measures. However, these agri-environmental plans present evaluation difficulties and problems of adverse selection and windfall effects (Barbut and Bashet, 2005; Bonnieux, 2005; Dupraz and Pech, 2007). Lastly, these instruments, which rely on a voluntary and temporary process of contractualisation, beg the issue of the robustness of this type of policy, just as much on the environmental plane (permanence of effects in case contracts are note renewed) as on the financial plane (cost borne by the community) (Mollard *et al.*, 2003).

The AEM tool, Agri-Environmental Schemes, today is not strongly oriented toward the quantitative management of water resources. In fact, among the fifty odd AEMs proposed and that a territory can potentially mobilise, only one (commonly called AEM "*Désirrigation*"[6]) aims at limiting irrigation of field crops: it consists of giving up one source of water withdrawal in exchange for a payment compensating the loss of crop yield associated with irrigation stoppage.

2.4. Stiffening of water management Policy

French water policy rests on three laws (1964, 1992 and 2006), which set up the co-ordinated and decentralised management[7] of water resources and which gave rise to the creation of management tools affecting the behaviour of economic agents vis-à-vis such resources. The most recent law, the LEMA (*Loi sur l'Eau et les Milieux Aquatiques* - Law on Water and the Aquatic Environment, which is the national transposition of the European Water Framework Directive 2000/60/EC) signals a change in paradigm in the manner of comprehending environmental policy since the management tools – established for the purpose of attaining, on the horizon of 2015, the objective of the "good status" for all water set by the DCE (EU Water Framework Directive) – are henceforth matched with an obligation of results on pain of financial sanctions. We now describe the different quantitative management tools of water resources implemented in the Charente-Maritime department[8].

[6] The AEM "Disirrigation" may be contractualised in the Charente-Maritime department since January 2011.

[7] The law of 1992 is at the origin of two new management tools (the SDAGE, concerning hydrographic basins, and its declension at the sub-basin level, the SAGE), developed in an action of "communication with resource users, even of their integration into the definition of water policy, so that the risks involved in the sustainable management may be collectively debated and defined in consultation and dialogue" (Petit, 2002, p. 279).

[8] We concentrate more especially on the instruments intended to regulate consumers' water usage in Charente-Maritime. In this study, we do not deal with the policy devoted to increasing supply. The agricultural world supports the implementation of reserves, perceived as a technical solution to the environmental problem, making ongoing irrigation possible. However, numerous objections surrounding these projects, notably about their real effect on the milieu, their method of financing and their statute, impedes (even prevents) the construction of reserves on several sub-basins.

On the quantitative plane, the local management of water resources relies on an incentive instrument, the water agency's "withdrawal" fees. The 1964 law on water is at the origin of the creation of six French water agencies given responsibility for levying usage fees from customers in function of their usage and in compensation for subsidy payments in support of investments to preserve the resource (Barraqué, 1995). The Charente-Maritime department is dependent on two water agencies, the Loire-Bretagne Agency for its northern part, and on the Adour-Garonne Agency for the south. The usage-fee system that water agencies employ is frequently blamed for not respecting the consumer-payer principle inasmuch as the payments of the heaviest users, in this case the farmers, are not aligned with their withdrawals from water resources.

The management of water resources in Charente-Maritime also relies on a coercive instrument: prefectoral orders during periods of quantitative crisis. At present, all withdrawals from the resource must be declared and may be limited (withdrawal restrictions), even forbidden (withdrawal bans) by the Administration for reasons of public interest. Orders are thus given by the Prefect when thresholds at various nodal points for the various basins are breached, so as to ensure the needs of high-priority usage[9]. In addition, volumetric management has been progressively implemented in the department (Loubier *et al*., 2008). When thresholds established by the Administration are reached, the allocated volume is reduced in proportion to the severity of the quantitative crisis. Volumetric management makes possible an improved crisis administration and greater awareness by irrigating farmers of the necessity to think about their routine behaviour (ASCA, 2006). The Water Police Department is given responsibility for verifying that users respect these regulations. Over the past few years, a hardening of the regulatory policy encompassing water resources can be observed, in keeping with the obligation of results imposed by the LEMA. Thus, the pursuit of the quantitative objective – equilibrium between available resources and users' water withdrawals from each contributing basin – has translated in Charente-Maritime by the implementation of an annual reduction in authorised volumes for agricultural withdrawals since 2006.

All in all, while a process of better integration of environmental issues is underway within the first Pillar of the CAP, it seems that the economic objective still predominates in 2009; while over the same past few years, we observe in tandem the development of the agri-environmental policy and a stiffening of management policy for water resources. In this context, we will endeavour in the remainder of our article to evaluate the incidence of environmental policy instruments (agri-environmental measures and instruments for managing water demand) on farmers' irrigation behaviour in Charente-Maritime.

[9] The DOE (*Débit d'Objectif d'Étiage*) is the threshold value of water flow above which are assured the normal coexistence of all consumers and the efficiency of the aquatic environment. The DCR (*Débit de crise*) is the threshold under which consumers with priority are in danger (in first instance the supply of drinking water, and secondly, the survival of species present in the milieu). The DOE is supposed to be respected 8 out 10 years, but because of the quantitative state of water resources in Charente-Maritime, crisis management is recurrent.

3. Data and model description

We marshal an original database covering the various information furnished in CAP subsidy claims by farmers for the years 2003, 2006 and 2009[10]. We carry out our econometric analysis on the Charente-Maritime department, which counts 4,864 farm holdings. We complement these data with elements relating to the agri-environmental policy and to the environmental policy in force over this territory, our objective being to estimate the incidence of these elements on the farmers' behaviour with respect to water resources. More precisely, we propose in this study to measure the effect of such instruments on routine irrigation behaviour through econometric modelling.

Out of the 4,864 farms existing in 2003, 1,502 were irrigated, which is more than 30% of farm holdings in Charente-Maritime. Out of these 1,502, more than 80% were still irrigated in 2009. Lastly, for our 1,231 farms irrigating in both 2003 and 2009, the irrigation intensity (share of irrigated land surface in the utilised agricultural area) diminished by 24.31% over the period (cf. Figure 1). We use a double-selection switching model[11]. We thus carry out a two-step estimation with two terms to correct for selection bias. The first probit regression tests the probability of irrigating in 2003 for the set of all farms in Charente-Maritime (4,864 agricultural firms). The second probit estimation tests, among the population of the farms that did irrigate in 2003, the probability of still irrigating in 2009. Finally, the third equation tests, for farm holding's irrigating in 2003 and in 2009, the growth rate of irrigation intensity between 2003 and 2009 (the proportion of irrigated land surface in the utilised agricultural area by each farm that irrigated in both years).

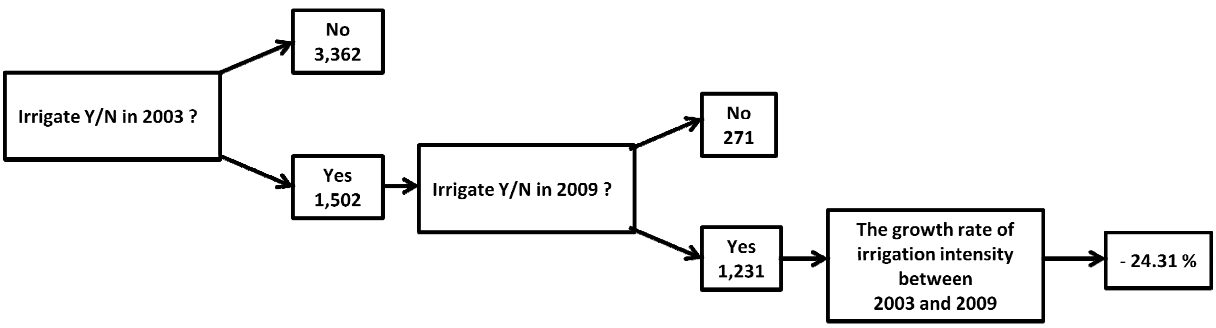

Fig. 1. Distribution of farm holdings in the database as of function of their irrigation behaviour.

Our model may be formalised in the following form:

$$I_i^* = Z_i\gamma + u_i \qquad (1)$$

$$A_i^* = B_i\mu + v_i \qquad (2)$$

$$0{,}5 \ln\left(\frac{1+T_i}{1-T_i}\right) = \beta_{irrig}X'_{irrig,i} + \alpha_{irrig}\hat{\lambda}_{0,i} + \eta_{irrig}\hat{\lambda}_{1,i} + \epsilon_{irrig,i} \qquad (3)$$

[10] We work with constant samples, which is to say that the farms present in our database were active during each of the three years considered – no new farm appearing, nor existing one disappearing between the three dates.

[11] Our model is based on the specification of Heckman (1979), Maddala and Nelson (1975) and Tunali (1986).

$I^*$and A^* are latent variables. Z is a vector representing the variables determining the probability of irrigating in 2003 (Z_i), and B is the vector representing the variables determining the probability of irrigating in 2009 (B_i). The estimated coefficients are represented respectively by γ and μ, and the error terms by u_i and v_i. T designates the growth rate of irrigation intensity – the evolution of the proportion of irrigated land in utilised agricultural area (UAA).

Since the latent variables are not observable, two functions are defined as follows:

On the act of irrigating in 2003:

$$I_i = 1 \; if \; I_i^* \geq 0$$
$$I_i = 0 \; if \; I_i^* < 0$$

If the farmer irrigates, then I_i = 1, and I_i = 0 if he does not.

On the act of irrigating in 2009:

$$A_i = 1 \; if \; A_i^* \geq 0$$
$$A_i = 0 \; if \; A_i^* < 0$$

If the farmer irrigates in 2009, then A_i = 1, and A_i = 0 if he does not, these later two variables being observed only if I_i = 1.

In equation (3), we use the reciprocal function of the hyperbolic tangent of the growth rate of irrigation intensity over the 2003-2009 period (situated within the interval]-1 ; 1[) so as to constrain our explained variable to lie between – ∞ and + ∞. The characteristics of the agricultural firms irrigating on both dates are represented by $X'_{irrig,i}$, the vector of coefficients to be estimated by β_{irrig}, and the errors by $\in_{irrig,i}$ (*cf. infra*).

Our model is estimated in the following way:

First, we estimate a probit model concerning the probability of irrigating in 2003 (Probit 1) so as to estimate the inverse of the Mills ratio λ_0, which is linked to the probability of irrigating in 2003. This ratio, by capturing the probability that a farm irrigates in 2003, whether it continued to do so or not in 2009, plays the role of selection correction term. Thus, the value of the dependent variable in this probit estimate assumes the value 1 if the farm irrigates and 0 if it does not. The explanatory variables in this probit regression are: the farm's total cultivated area, its legal form (three types), and the nature of its current crops (four types) – in all cases for the year 2003.

Secondly, we test a new probit model concerning the probability of irrigating in 2009 (Probit 2), enabling us to construct a second selection-bias correction term inasmuch as the equation for the growth rate of irrigation intensity between 2003 and 2009 can only be observed for the farms continuing to irrigate in 2009. We have therefore constructed the inverse of the Mills ratio $\lambda_1$for the case irrigation has not been discontinued in 2009. Here again, the dependent value of the probit estimation takes on the value 1 if the farm irrigates and 0 if not. The explanatory variables in this probit model are the same as those of the first one, to which we add three other control variables (the share of irrigated land in the UAA in 2003, its square and the growth rate of the UAA over the period) and three variables relating to the environmental policy (the number of prefectoral water-usage restriction days, irrigation usage fees and AEM).

The estimated bias-selection correction terms included in the equation for the irrigation intensity growth rate between 2003 and 2009 are:

$$\hat{\lambda}_{0,i} = \phi\,(Z_i'\hat{\gamma})/\Phi(Z_i'\hat{\gamma})$$
$$\hat{\lambda}_{1,i} = \phi\,(B_i'\hat{\mu})/\Phi(B_i'\hat{\mu})$$

(in which ϕ is the standard normal distribution function and Φ its cumulative distribution function).

The inverses of the Mills ratio are introduced as supplementary terms in the equation for the irrigation intensity growth rate (Equation 3). The coefficients of the inverses of the Mills ratio (α_{irrig} and η_{irrig}) capture the effect of the correlation of error terms in the estimation of selection processes (irrigation in 2003, irrigation not discontinued in 2009) and in the estimation of the irrigation intensity growth rate. Our Equation 3 thus describes the irrigation intensity growth rate, while taking into account the selection in case of irrigation in 2003 and non-curtailment in 2009[12].

We employ two types of explanatory variables (cf. Table 1): variables originating from the file of CAP declarations and the variables relating to policy instruments. The first type of explanatory variables is related to the farms' characteristics in Charente-Maritime over the 2003-2009 period – control variables. We complete these data with elements relating to agri-environmental and environmental policies. On the basis of a review of administrative acts drawn up from 2003 to 2009, we selected the contributing basins in Charente-Maritime that were concerned by the prefectoral orders of water-usage restrictions. We constructed a variable that is capable of accounting for the number of prefectoral water-usage restriction days in 2003 (*j0*, *j1*, *j2*, *j3*, *j4*). We also constructed, from the Water Agencies' water "withdrawal" fees, a variable (*Water.Fee*) that represents the water-usage fee rate per hectare applied to the different farms. Finally, we distinguished, using a binary variable, the farms that had subscribed to contractual agreements in 2009 under an AEM (*AEM*). We do not use the variables relating to subsidised land surfaces – land surfaces benefiting from CAP support – in our econometric analysis because all irrigated land surfaces have necessarily been granted premiums (the irrigated land surfaces being therefore included in the subsidised surfaces).

[12] We carried out complementary tests: correction by the White matrix for the heteroscedasticity.

Table 1: Characteristics of the variables used in the double-selection switching model.

	Variable	Description	**The whole set of farm holdings** **n = 4,864**			**The farm holdings that irrigate in 2003** **n = 1,502**			**The farm holdings that continued to irrigate in 2009** **n = 1,231**		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Control Variables	**UAA**	*Utilised Agricultural Area in 2003 (hectares)*	1	672.6	66.9	1.6	672.6	104.7	2.7	673	111.7
		Farm holding's legal form in 2003:									
	STAT1	Individual	0	1	0.68	0	1	0.48	0	1	0.44
	STAT2	Corporate (French GAEC or EARL civil companies)	0	1	0.26	0	1	0.45	0	1	0.49
	STAT	Other	0	1	0.06	0	1	0.07	0	1	0.07
		Shares of crop in UAA in 2002, (crop area/UAA) in %:									
	CEREALS	Cereals	0	100	45.6	5	100	57.2	5	100	58.1
	OILSEEDS	Oilseed crops	0	100	16.3	0	66.3	10.6	0	52	10
	PROTEINS	Protein crops	0	90.1	1.32	0	47.5	2	0	47.5	2.2
	OTHER	Other	0	100	36.8	0	95.1	30.2	0	95.1	29.6
	IRR.area	*Share of irrigated land in UAA in %*	*Only for irrigating farm holdings* 0.9	100	34.3	0.9	100	34.3	2.4	100	36.1
	IRR.area²	*Square of the share of irrigated land in UAA in %*	*Only for irrigating farm holdings* 0.01	100	15.75	0.01	100	15.75	0.06	16.72	100
	UAA.growth	*Growth rate of the UAA between 2003 and 2009 in %*	- 99.6	1,824	4.6	- 99.4	645.3	4.8	- 87	645.3	9.4
Environmental Policy		*Number of prefectoral water-usage restriction days in 2003*									
	j0	*0*	0	1	0.05	0	1	0.1	0	1	0.11
	j1	*69 or 74*	0	1	0.37	0	1	0.3	0	1	0.31
	j2	*88 or 90*	0	1	0.15	0	1	0.15	0	1	0.14
	j3	*95 or 98*	0	1	0.31	0	1	0.3	0	1	0.3
	j4	*109*	0	1	0.11	0	1	0.16	0	1	0.15
	Water.Fee	*Water withdrawal fee per hectare in 2003 (Water withdrawal fee / Irrigated land)*	*Only for irrigating farm holdings* 0	91.9	11.3	0	91.9	11.3	0	91.9	11.4
	AEM	*Contractual agreement under an Agri-Environmental Scheme in 2009*									
		Yes	0	1	0.06	0	1	0.1	0	1	0.89
		No	0	1	0.94	0	1	0.9	0	1	0.11

Table 2: Expected effects of tested variables

<table>
<tr><th colspan="2">Variables tested</th><th>Probit 1
n = 4,864</th><th>Probit 2
n = 1,502</th><th>Equation 3
n = 1,231</th></tr>
<tr><td rowspan="6">Control variables</td><td>UAA</td><td colspan="3">+</td></tr>
<tr><td>STAT1
STAT2
STAT</td><td colspan="3">Ref
?
?</td></tr>
<tr><td>CEREALS
OILSEEDS
PROTEINS
OTHER</td><td colspan="3">Ref
-
-
-</td></tr>
<tr><td>IRR.area</td><td rowspan="6"></td><td colspan="2">+</td></tr>
<tr><td>IRR.area^2</td><td colspan="2">-</td></tr>
<tr><td>UAA.growth</td><td colspan="2">+</td></tr>
<tr><td rowspan="3">Environmental Policy</td><td>j0
j1
j2
j3
j4</td><td colspan="2">Ref
-
-
-
-</td></tr>
<tr><td>Water.Fee</td><td colspan="2">-</td></tr>
<tr><td>AEM</td><td colspan="2">-</td></tr>
</table>

Table 2 shows the various expected effects of the different explanatory variables that appear in our econometric analysis.

We begin by testing the weight of variables relating to the farm's characteristics. Regardless of the observed explanatory variable, we do not predict a priori different effects between the three stages of our econometric analysis (Probit 1, Probit 2, Equation 3). We wish first of all to observe whether the size of the farm, as measured by the farm's utilised agricultural area (*UAA)*, has an effect on the farmer's behaviour. More precisely, we are attempting to measure the existence of a potential effect of holding size, and we thus expect to find that the size of the farm has a positive impact on irrigation behaviour. We will then investigate with the model the variables relating to the farm's legal status (*STAT1*, *STAT2*, *STAT*) without presuming a particular effect. Inasmuch as the cereal crops are usually the most irrigated plants, we believe that, in comparison with cereals (*CEREALS*), the other crop types (*OILSEEDS*, *PROTEINS*, *OTHER*), should have a negative impact on farmers' irrigation behaviour.

We add new control variables to the Probit 2 model and to Equation 3. By means of the variable *IRR.area* (share of irrigated land in the UAA for 2003), we are seeking to test the weight of the past in agricultural behaviour, and in particular the existence of an inertia phenomenon (effect presumed positive). However, given that the variable *IRR.area* assumes values between 0 and 100%, we may expect its influence on irrigation behaviour to be non-linear (positive influence up to a certain threshold, and negative thereafter). We therefore introduce the variable *IRR.area* and its square ($IRR.area^2$) into the Probit 2 estimation and Equation 3. The variable *UAA.growth* (growth rate of utilised agricultural area between 2003 and 2009), enables us to test for the role of agricultural concentration on irrigation behaviour (positive expected effect).

Lastly, we integrate the variables that relate to environmental policy. By such means, we attempt to observe whether environmental policy has an impact on agricultural behaviour with respect to water resources. The policy instruments implemented over the territory are theoretically supposed to restrict water resource usage. We therefore expect a negative effect on irrigation behaviour for the variables we constructed (negative effect of *j1, j2, j3 and j4* in comparison with *j0* for the number of restriction days and negative effect of *Water.Fee* for the water withdrawal fee per hectare in 2003). Since no agri-environmental scheme *AEM* directly linked to irrigation existed in Charente-Maritime in 2009, our *AEM* variable appears as a proxy for farmers' environmental sensitivity, and we thus expect a negative effect on irrigation behaviour in the department.

5. Results and discussion

The Probit 1 regression exhibits a pseudo-R^2 of 0.26. Probit 2's pseudo-R^2 is 0.29. Thirdly, the Equation 3 results display an R^2 of 0.13 and thus make it possible to capture part of the explanation for the growth rate of irrigation intensity. Lastly, only the second Mills ratio is significant, hence bias does not seem to exist in the case of Probit 1. The correct prediction rate is around 79 % in Probit 1 and around 87 % in Probit 2 (cf. Table 3).

The variable *UAA* is strongly significant (at the 1% level for the two probits and at the 5% level in Equation 3), having a positive effect in the three equations in our econometric model, which confirms our predictions relating to the existence of the size effect in irrigation behaviour. The UAA thus positively influences the probability of irrigating in 2003, the greater a farm's utilised agricultural area, not only the greater its probability of irrigating, but also the greater its chances of continuing to irrigate in 2009. The effect of holding size also affects irrigation behaviour dynamically: the more a farm has a large UAA in 2003, the greater its tendency to increase the share of irrigated land area in its UAA between 2003 and 2009. These findings relating to UAA effects confirm our predictions about the positive role of agricultural concentration on irrigation behaviour.

STAT2 has a significant effect (at the 1% level) and its sign is positive in Probit 1. Thus, operating under the French civil corporate forms, a GAEC or an EARL, rather than as a sole proprietorship (represented by the reference variable STAT1) exerts a positive influence on the probability of irrigating. Stated otherwise, farms that are sole proprietorships have a lesser tendency to irrigate than the GAECs or EARLs. This phenomenon brings us back to the idea that farms with greater numbers of people in charge (shareholder types) have a greater probability of irrigating. However, this variable has no further impact on dynamic irrigation behaviour, be it the probability of irrigating in 2009 or the evolution of irrigation intensity over the period since its effect is non-significant in the Probit 2 equation and in Equation 3. Because of this, the findings concerning the UAA and the farm's legal status may in our opinion be ascribed to the concentration and irrigation behaviour developed in the 1970s.

Table 3: Results

Variables tested	**Probit 1** The probability of irrigating in 2003 n = 4,864		**Probit 2** The probability pf still irrigating in 2009 n = 1,502		**Equation 3** The growth rate of irrigation intensity (2003-2009) n = 1,231
UAA	0.01 ***	0.31	0.007 ***	0,12	0,001 **
STAT1			*Ref*		
STAT2	0.296 ***	9.81	0.125	2,21	0,018
STAT	0.089	2.91	- 0.285	-5,90	- 0,021
CEREALS			*Ref*		
OILSEEDS	- 0.037 ***	- 1.19	- 0.007	- 0,12	- 0,004
PROTEINS	- 0.008 *	- 0.26	0.017	0,31	- 0,006 **
OTHER	- 0.019 ***	- 0.61	0.007 *	0,12	0,003 **
IRR.area			0.086 ***	1.53	0,009 ***
IRR.area²			- 0.074 ***	- 1.32	- 0,008 **
UAA.growth			0.017 ***	0.3	- 0,000
j1			- 0.274	- 5.23	- 0,178 ***
j2			- 0.409 **	- 8.69	- 0,221 ***
j3			- 0.443 **	- 8.83	- 0,244 ***
j4			- 0.511 **	- 11.23	- 0,197 ***
Water.Fee			0.009	0.15	0,001
AEM			0.162	2.65	- 0,047
Mills1					0.011
Mills2					0.677 ***
Pseudo R²	0.26		0.29		/
R²	/		/		0.13
LR	1,569.1 ***		491.5 ***		/

Note: We report the coefficients in the first column (with the significance levels represented by stars) and the marginal effects in the second column.

The variables describing cropping practices (*OILSEEDS, PROTEINS, OTHER*) are all three significant (two at the 1% and one at the 10% levels), and their effect on the probability of irrigating in 2003 confirms our predictions: the greater the share of oilseeds, proteins or others crops (the latter being neither oilseeds, nor proteins, nor cereals) in the UAA by comparison to the share of cereals (CEREALS, the reference variable), the weaker the probability of irrigating. Thus, the farm holdings specialised in cereals (among which maize figures) have a higher probability of irrigating than the others. The *PROTEINS* variable goes on to be significant (at the 5% threshold, and the sign is again negative) for the growth rate of irrigation intensity. It does not have an effect on the probability of continuing to irrigate in 2009, but exerts a positive influence on irrigation intensity between 2003 and 2009. The *OTHER* variable is significant at the 10 % level in Probit 2 and at 5 % level in Equation 3 but with a negative sign. This last result deserves complementary investigation.

The variable *IRR.area* represents the share of irrigated land in the UAA for each irrigating farm holding in 2003. It is significant at the 1% level, with a positive coefficient, in the Probit 2 regression and Equation 3. Thus, the greater the irrigated land area in the UAA – or to put it otherwise, the greater the irrigation intensity in 2003 – the higher the probability the farm still irrigates in 2009, and the greater the tendency to increase irrigation intensity. Here again can be found the effect of a certain behavioural inertia, even of a reinforcement of irrigation behaviour on farms that irrigated already in 2003. However, the *IRR.AREA*^{2} variable is also significant at the 1% threshold in Probit 2 and at the 5 % threshold in Equation 3, but its coefficient has a negative sign, translating the existence of a ∩-shaped curve for the share of irrigated land area in the UAA and confirming our predictions.

UAA.growth (growth rate of the UAA between 2003 and 2009) has a very significantly positive effect in the Probit 2 equation (at the 1 % level). Thus, the more the UAA increases over the period, the greater the probability the farm will continue to irrigate in 2009. On the other hand, the evolution of the UAA over the period does not have an effect (non-significant in Equation 3) on the evolution of irrigation intensity. Therefore, the rise in the UAA increases the probability of maintaining irrigation on the farm in 2009, but it does not influence the evolution of irrigation intensity. Bringing together this finding with the results relating to the *UAA*, it is possible to say that the large-scale farms of 2003 have a greater tendency to continue irrigation in 2009 and to reinforce irrigation presence over the period (an increase in irrigation intensity) and that the increase in farm size *(UAA.growth*) works in favour of maintaining irrigation on the farm, but it does not have an effect on the evolution of irrigation intensity.

The first variable relating to the quantitative management of water resources in Charente-Maritime is the number of prefectoral water-usage restriction days in 2003. Each modality of the variable (*j1, j2, j3, j4*) has a significant coefficient (only the modality *j1* is not significant in Probit 2) at the 5 % threshold in Probit 2 and the 1 % threshold in Equation 3. Thus, the number of restriction days negatively influences the probability of continuing to irrigate in 2009 and the evolution of irrigation intensity. In other words, this policy instrument has an impact on the decision "I stop or do not stop irrigation between 2003 and 2009" and on the evolution of the share of irrigated land area in the UAA.

The variable *Water.Fee* (incentive instrument), on the other hand, is non-significant in the Probit 2 equation and in Equation 3. This result may be easily explained. Actually, in spite of the water-fee system reform that the LEMA imposes, the water fee at its current rate presents problems of equity between consumers inasmuch as those who make the greatest withdrawals from water resources, the farmers, only pay a fraction of the share of total fees collected by the water agencies as water withdrawal levies[13]. It also presents problems as incentives for economising water usage because of the low level of water-withdrawal fees for farmers. In fact, it has been shown that the incentive effect appears at rates higher than 9 centimes/m^3 (Montginoul, 1997). Yet, in Charente-Maritime, the rate applied by the two water agencies is inferior to 1 centime/m^3. The withdrawal fees in this case only constitute budget receipts that assure the water agencies' budgetary equilibrium. These elements explain why the "water-fee" tool, at the rate applied in Charente-Maritime, does not have a convincing effect on the dynamics of irrigation behaviour.

The variable *AEM* (contractual agreement under an Agri-Environmental Scheme in 2003) is non-significant in the Probit 2 equation and in Equation 3. This result goes against our

[13] Part of the gap may be explained by the services linked to the treatment and the adduction of drinking water from which the farmers do not benefit. It is important nevertheless to specify that the water usage fee is not the sole cost element for farmers (energy cost of water withdrawals, equipment depreciation).

intuitions since farmers who had subscribed to agreements under an AEM in 2009 did not have a greater tendency to diminish irrigation intensity on their farms than the others.

On the aggregate, the best that can be said of State interventions in water resource management is that the results are mixed. Only the “prefectoral water-usage restriction orders” tool has had a significant effect on farmers’ irrigation behaviour in Charente-Maritime. The local management of water resources that relies on an incentive instrument – irrigation usage fees – or on voluntary agreements – AEM – seems to have an insignificant impact on the evolution of farmers’ behaviour with respect to the water resource. As we have already indicated, the strong presence of productivist farming operations in the Charente-Maritime department, the current context of agricultural sector liberalisation and the additional premium for irrigation – still in existence in 2009 – are counterproductive to the reduction in irrigated land areas. Thus, market constraints and irrigation benefits in agriculture can explain farmers’ behaviour: farmers reduce their irrigated land areas only if they are forced, that is to say with coercive instruments like prefectoral water-usage restriction orders.

6. Conclusion

Due to the important agricultural water withdrawals in Charente-Maritime, several State instruments have been implemented to control water management and to reduce the pressures of irrigation on water resources. In this study, we question the incidence of these instruments on the evolution of irrigation practices.

Farmers’ behaviour with respect to water resources is not only impacted by the instruments stemming from environmental policy. Actually, agriculture sector policy, by shaping farmers’ productive strategies, also influence their relationship to the environment. We thus bring to light, in the first part of this study, the existence of potential contradictions: on the one hand within the CAP between economic objectives and environmental objectives, and on the other hand between agricultural and environmental policies. Through econometric modelling effectuated on data from farms in Charente-Maritime between 2003 and 2009, we were then able to show that while environmental policy (agri-environmental measures and instruments for water demand management) does influence farmers’ irrigation behaviour, it does so in a way that is rather marginal.

These contrasting results raise the question of the modification and/or of the evolution of the quantitative management of water resources in Charente-Maritime. Should the coercive instruments be further reinforced, or should greater incentives be provided to encourage agents to modify their practices (incentive instruments, voluntary approaches…)? The answer to this question relies in the evolution of agricultural policy. Indeed, while environmental considerations are increasingly integrated in the agricultural productive process, when irrigation supports the logic of intensified agriculture (which is the case in Charente-Maritime), the incentives derived from the sector’s liberalisation, reinforced by the upward trend in agricultural prices, still remain elements that call into question the pertinence of voluntary and incentive instruments when the issue is to modify irrigation behaviour. Finally, we believe that our work could be enriched by the analysis of the most recent CAP reforms, notably the discontinuance of increased premium payments for field crops and irrigation), in such a way as to estimate whether these evolutions have an effect on our results concerning determinants of farmers' behaviour with respect to the water resource.

Appendix

Table A1. Description of the explanatory variables in the double-selection switching model

	Variable	Measurement Unit	Source	Description
Control Variables	UAA	Hectares	DRAAF Data	Utilised Agricultural Area (UAA) in 2003
	STAT1 STAT2 STAT	Binary variable	DRAAF data	Farm holding's legal form in 2003: Individual Corporate (French GAEC or EARL civil companies) Other
	CEREALS OILSEEDS PROTEINS OTHER	%	DRAAF data	Shares of crop in UAA in 2002 (crop area/UAA) : (Cereals area/UAA) x 100 (Oilseeds area/UAA) x 100 (Proteins area/UAA) x 100 (Other area/UAA) x 100
	IRR.area	%	DRAAF data	Share of irrigated land in UAA in 2003 in %
	IRR.area²	%	DRAAF data	Square of the share of irrigated land in UAA in 2003
	UAA.growth	%	DRAAF data	Growth rate of the UAA between 2003 and 2009
Environmental Policy	j0 j1 j2 j3 j4	Binary variable	DRAAF data	Number of days of water-usage restrictions in 2003: 0 69 or 74 88 or 90 95 or 98 109
	Water.Fee	Ratio	Water agencies data	Water withdrawal fee per hectare in 2003 (Water withdrawal fee/irrigated land area)
	AEM	Binary variable	DRAAF data	Contractual agreement under an Agri-Environmental Scheme in 2009: 1 Yes 2 No

Table A2. Results

Probit 1 : The probability of irrigating in 2003

	Estimate	Std. Error	Significance
(Intercept)	-0.082	0.062	
UAA	0.01	0.001	***
STAT2	0.296	0.057	***
STAT	0.089	0.098	
OILSEEDS	- 0.037	0.002	***
PROTEINS	- 0.037	0.005	*
OTHER	- 0.019	0.001	***

*Notes : *P<0.1, **P<0.05, ***P<0.01*

Probit 2 : The probability of still irrigating in 2009

	Estimate	Std. Error	Significance
(Intercept)	-1.259	0.335	***
UAA	0.007	0.001	***
STAT2	0.125	0.112	
STAT	- 0.285	0.193	
OILSEEDS	- 0.007	0.006	
PROTEINS	0.017	0.011	
OTHER	0.007	0.004	*
IRR.area	0.086	0.008	***
IRR.area²	- 0.074	0.008	***
UAA.growth	0.017	0.002	***
j1	- 0.274	0.186	
j2	- 0.409	0.205	**
j3	- 0.443	0.193	**
j4	- 0.511	0.202	**
Water.Fee	0.009	0.006	**
AEM	0.162	0.185	

*Notes : *P<0.1, **P<0.05, ***P<0.01*

The growth rate of irrigation intensity between 2003 and 2009

	Estimate	Std. Error	Significance
(Intercept)	- 0.528	0.128	***
UAA	0.001	0.000	**
STAT2	0.018	0.034	
STAT	- 0.021	0.048	
OILSEEDS	- 0.004	0.002	
PROTEINS	- 0.006	0.002	**
OTHER	0.003	0.002	**
IRR.area	0.009	0.004	***
IRR.area²	- 0.008	0.003	**
UAA.growth	- 0.000	0.000	
j1	- 0.178	0.042	***
j2	- 0.221	0.049	***
j3	- 0.244	0.046	***
j4	- 0.197	0.049	***
Water.Fee	0.001	0.002	
AEM	- 0.047	0.04	
Mills1	0.011	0.090	
Mills2	0.677	0.106	***

*Notes : *P<0.1, **P<0.05, ***P<0.01*

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