Spatial structure of French dairy sector: a spatial HAC estimation

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3èmes journées de recherches en sciences sociales

INRA SFER CIRAD

09, 10 & 11 décembre 2009 –Montpellier, France

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JEL Classifications: C21, C14, R12

Abstract

This paper provide insight into the spatial structure of the French dairy sector, helping to gain a better understanding of the agglomeration and dispersion forces that influence the location of dairy farms in France in 1995 and 2005. We use the non-parametric heteroskedasticity and autocorrelation consistent (HAC) parameter covariance estimator proposed by Kelejian and Prucha (2007), which enables us to handle simultaneous equations and spatial endogeneity. Results show that market conditions and agglomeration economies now play a more important role in the location of farms than they used to because of the reduced domestic support for agriculture. In addition, environmental regulations have a negative impact on dairy farm location and may play a role of dispersion force.

Key words: Dairy sector, Spatial Econometrics, Agglomeration, Policy Subsidies, Environmental regulations

Introduction

The French dairy sector is undergoing significant structural changes in response to a new market environment. In fact, government intervention in the regulation of agricultural markets has been reduced over time. In particular, the 2003 Luxembourg Agreement on the reform of the Common Agricultural Policy (CAP) has strongly modified the structure of the subsidies provided to dairy farmers by simultaneously reducing the milk support prices and introducing a direct payment system. Therefore, milk prices are less regulated which tends to increase their inherent volatility; volatility which is due to the inelastic nature of the demand for dairy products and the rigidity of the production cycle. As a result of these policy reforms, dairy farms are more than ever encouraged to better adjust their production to market signals.

The dairy sector is undergoing changes in terms of numbers, size and productivity of dairy operations. As in most agricultural sectors, there has been a general tendency toward fewer, yet larger, farms. According to the French Census of Agriculture, the number of dairy farms has declined by 38%, from 161,225 farms in 1995 to only 99,374 in 2005. In fact, the decrease in the number of dairy farms was unavoidable since domestic consumption and export demand for dairy products remained fairly stable over this period. On the other hand, the average number of dairy cows per farm increased from 29 in 1988 to 40 in 2005, which illustrates the trend towards the adoption of more intensive production systems and so, the gain in scale economies. Moreover, the milk yield per cow has increased considerably thanks to technological, and mainly, genetic advancements. However, the capacity to adapt to the new market environment differs between regions. Consequently, these changes in the French dairy sector have occurred at different rates in different geographical areas of the country. The "Grand Ouest", which is the main productive area comprises Brittany, Pays de la Loire and Basse-Normandie regions, accounts for 47 % of the national production with 11 billion litres of cow's milk in 2005 and represents the biggest concentration of dairy farms (42 % of the total number of dairy farms in 2005) (see Figure in Annex 1). These regions have followed a highly industrialized pattern of production with herd sizes larger than the national average and the rate of disappearance of dairy farms in these regions also slower than in the rest of France. Indeed, dairy farms in Western France, are generally more competitive in terms of milk production cost, collection and transport cost, and have been able to better adapt to this new economic environment. However, this is not the case in other traditional dairy regions, located in mountain areas, which represent a non-negligible 20 % of French dairy farmers. In fact, there are important structural and quantitative differences between farmers operating in mountainous regions and those in other areas: a mountain farm produces 175 000 litres of milk on average against the 276 000 litres produced by a farm situated in a plain region. Moreover, the cost of milk production in the mountains is 4 to 15 % higher and collection costs are 12 € higher per 1000 litres of milk. However, the price of milk in the mountains is higher than the price in plain because of the valorisation of the quality of milk as quality certified product (Livestock Office). As a consequence, these regions - less competitive and therefore highly dependent on State subsidies – struggle more in the new market environment.

This structural process, heterogeneous in space, can lead to two important problems: the desertification of disadvantaged areas and a high concentration of large farms in competitive regions. Consequently, the productive landscape that we have known until now may change. Firstly, the disappearance of dairy production in disadvantaged areas, such as mountainous and isolated regions, may lead to social problems. Indeed, agricultural activities in these areas account for 10 % of all employment. Moreover, dairy activities play an important role in maintaining the density of rural and open areas, contributing to environmental protection as well (preservation of biodiversity, maintenance of permanent grassland, protection against the risk of erosion, flood or fire...). Secondly, with regard to competitive areas, the increasing concentration of larger farms is not necessarily coherent with the growing public concern about environmental degradation. Furthermore, these concerns are justified since the main productive regions are located in environmentally sensitive areas and contribute significantly to air and water pollution. Increasing environmental awareness has led the EU to implement new environmental regulations in order to reduce the negative impacts of livestock production on the environment (Nitrate Directive, Global Monitoring for Environment and Security).

In this changing context, this research attempts to shed some light on the three following topics: i) Is spatial clustering an important feature of the dairy sector? ii) What determinants influence spatial and structural changes in dairy sector? iii) Have agricultural policies and environmental regulations had an impact on dairy farm location? In order to answer these questions, we use a spatial econometric model of the number of dairy farms at the *département* level in France for the years 1995 and 2005. We estimate our model using the methodology recently developed by Kelejian and Prucha (2007). The methodology is a 2SLS spatial model, which provides us with a non-parametric heteroskedasticity and autocorrelation consistent (HAC) estimator of the parameter variance-covariance (VC) matrix. To our knowledge, this methodology has not been applied in previous literature on agricultural production location.

The paper is organized as follows. In the next Section, we start with a review of literature and present the empirical model. Following this, we describe the data used in the analysis and then present and discuss the results. We conclude in the last Section.

Literature review

Few studies are interested in the spatial distribution of agricultural production. Gillmor (1987) used a geographical approach to analyze the concentration of enterprises and spatial change in agriculture of the Republic of Ireland. Abdalla et al. (1995) have discussed the factors influencing location decisions and regional shifts. Osei and Lakshminarayan (1996) looked at the determinants of dairy farm location in the US focusing on the role of environmental policy indicators. Roe et al. (2002) modelled the spatial structure of hog farms in the US using a spatial lag model. Gillespie and Fulton (2001) introduced a spatial dimension in the Markov model to study the size distribution of hog production firms in the US. Recently, Isik (2004) studied the spatial structure of the US dairy sector, focusing more particularly on the impact of environmental regulation. He explicitly used a spatial lagged model.

Location theory more appropriately addresses the economic choice of firm location and production in space, but this introduces space as it will be used at the decision-maker's level.
It is assumed that a farmer's land allocation decisions depend on the prices of the key inputs facing that farmer. In dairy production key inputs include animal feed. Another important factor is the price of milk. This assumption is based on basic profit motives in microeconomic theory. However the prices of agricultural commodities are normally related to their relative distance from key markets. In general when a commodity is produced further from a market it receives a higher price. This is how the location of a farm affects the prices of the commodities it produces. When the prices of commodities are included in the model, the distance between the farm and the market may not need to be included since its cost should be accounted for in the price (Brewin, 2004).

According to Blair and Premus (1993) the location theory in economics evolved from a simple minimization of transportation cost integrating two location factors: access to markets and access to materials. As the theory progressed, other factors - prices and market structure, state and local taxes, regional business climates, factors related to quality of life and other regional differences - were integrated into increasingly complex models of the firm location process.

Many authors, including Barkley and Keith (1991) and Bartik (1989) have studied why specific types of firms locate in different regions. Various factors affect the choice of firm location. Most of the studies in this area ignore local natural endowments. They instead look at community infrastructures, tax levels and available incentives.
The fact that local resources are not taken into account could be due to their being difficult to measure or complex relationships between industries and those natural resources, which makes these relationships difficult to confirm theoretically.

Agriculture makes use of local natural resources that are fairly well measured. Several factors can influence farmers' location decision: the availability of good farm land, rainfall and perhaps the availability of livestock, labour, materials and services. Previous studies, which have identified and ranked location decision factors, have found that farmers were also likely to consider environmental and policy factors.

Approach

In this study, we follow the comprehensive behavioural model of dairy farm location as developed by Isik (2004). Here firms operate in a two-dimensional spatial world and face transportation costs for inputs and outputs. Under an expected utility maximization formulation, Isik derives first order conditions for input use and firm location. Given that a firm locates its operation where it achieves its highest certainty equivalent income, Isik notes that the location decision is related to how the firm judges both the expected profit and risk premium associated with a site. Features such as prices of (and access to) inputs and outputs, taxes, and regulations affect profits; while variations in temperatures and rainfall affect the risk premium. Isik stresses that agglomeration economies should also be considered as they can shape the competitive landscape.

Empirical Model

Many regional economic problems reveal the existence of spatial autocorrelation – because of the spatial interaction between economic activities – and of simultanous relationships between endogenous variables. Following Cliff and Ord (1981), the spatial econometric literature has developed a large number of methods that can address spatial heterogeneity and dependence by specifying a spatially lagged dependent variable (spatial autoregressive model), or by modelling the error structure (autoregressive disturbance model). In the absence of spatial autocorrelation, different methods such as instrumental variables or maximum likelihood can be used to estimate models with endogenous variables. However, the presence of endogeneity in a spatial context has generally been ignored. “As a consequence, researchers have often been in the undesirable position of having to choose between modelling spatial interactions ignoring feedback simultaneity, or accounting for endogeneity but losing the advantages of a spatial econometric approach” (Rey and Boarnet, 2004).

In this paper, we use Kelejian and Prucha’s (2007) method, which enables us to analyze both endogeneity and simultaneous spatial interaction. This method makes it possible to develop a non parametric heteroskedasticity and autocorrelation consistent (HAC) estimator of the parameter variance–covariance (VC) matrix, namely SHAC within a spatial context. In order to show the advantages of this approach, we will compare the Ordinary Least Squares (OLS) and the spatial autoregressive (SAR) model to the SHAC estimator.

Consider the classic OLS regression model:

$$y = Xb + \varepsilon \tag{1}$$

in which $\boldsymbol{y}$ is the $(n \times 1)$ vector of observations on the dependent variables; $\boldsymbol{X}$ is a $(n \times k)$ matrix of observations on k exogenous variables with $\boldsymbol{b}$ as the corresponding $(k \times 1)$ vector of parameters and $\boldsymbol{\varepsilon}$ is the $(n \times 1)$ vector of error terms. Classical OLS regression analysis ignores the spatial interdependence as well as the presence of endogenous variables. As a result, OLS will tend to inflate estimates of non-spatial regressors when spatial interdependence is present. Additionally, OLS standard errors will tend to be too low implying over-confident conclusions and so, non-spatial factors may be significant when they should not (Doreian et al. 1981; Doreian et al. 1984; Franzese and Hays, 2004).

Accounting for the spatial dependence, equation (1) is extended by a spatially lagged dependent variable (***Wy***):

$$y = \rho Wy + Xb + \varepsilon \tag{2}$$

where $\boldsymbol{\rho}$ is the scalar spatial autoregressive parameter and $\boldsymbol{W}$ is a $(n \times n)$ spatial weight matrix of known constants with a zero diagonal. An element w_{ij}^{*} of the matrix describes the link between an observation in location ***i*** and an observation in location ***j***, and so the ***W*** matrix represents the strength of spatial interaction between locations. There are different ways to define the spatial weight matrix: a binary contiguity matrix, a distance-based spatial weight matrix with or without a critical cut-off, and many others (Anselin, 1988; Fingleton, 2003). The simplest one is the first-order spatial contiguity matrix, where w_{ij} is equal to one if locations share at least a common border and zero otherwise. However, contiguity matrices appear restrictive in terms of their spatial connection definition (Cliff and Ord, 1981). Therefore, we also use a geographical distance function – as most of empirical studies have done (Fingleton, 1999, 2000; Le Gallo, 2002; Le Gallo et al. 2003; Rey and Boarnet, 2004) - defined as:

$$\begin{aligned} & w_{ij}^{*} = 0 \; if \;\; i = j \\ & w_{ij}^{*} = 1/d_{ij}^{2} \; if \;\; d_{ij} \le D \quad and \quad w_{ij} = w_{ij}^{*} \Big/ \sum_{j} w_{ij}^{*} \\ & w_{ij}^{*} = 0 \; if \;\; d_{ij} > D \end{aligned} \tag{3}$$

where $\boldsymbol{d_{ij}}$ is the great circle distance between the centroids of locations $\boldsymbol{i}$ and $\boldsymbol{j}$ and $\boldsymbol{D}$[1] is the critical cut-off. In our application $\boldsymbol{D}$ is equal to 115 km since it is the minimum distance that guarantees connections between all *départements*[2]. Each matrix is row standardized so that it is relative and not absolute distance that matters. The main advantage of using the geographical distance-based weights is that they can be considered as exogenous to the model and as a good proxy of transport cost (Arbia et al. 2009). However, these matrices assume equal importance to all *départements* located at a same geographical distance without taking into account the economic potential of the *départements* or their accessibility (Keilbach, 2000; Dall'Erba, 2004; Virol, 2006). To better represent real spatial interactions, we also use time-road distance where the cut-off $\boldsymbol{D}$ is 90 minutes. This weight matrix takes into account the accessibility in terms of the time needed to go from one location to another and also the road infrastructure between locations. However, because infrastructures may change (e.g. new highway) the time weight matrix can also change over time. However, because of the lack of data the same weight matrix – that of the year 2007[3]- is considered for the model of the year 2005 and that of the year 1995.

[1] The robustness of model is also tested by using others cut-off for geographical and time-road distance. However, we don't present all results since they are very similar.

[2] One of the large districts into which, France is divided for administrative purposes. France has 100 *départements* which are grouped into 22 metropolitan and four overseas regions. All regions have identical legal status as integral parts of France.

[3] The time weight matrix is provided by Odomatrix 2008, INRA UMR 1041 CESAER, Dijon ; from Route 500® IGN

The SAR model incorporates the effect of spatial dependence and heterogeneity, but does not address the presence of potentially endogenous variables on the right hand side, which can result in non zero covariances between these regressors and the disturbance term. This causes the SAR model's estimator to be inconsistent.

Now consider the following model where we distinguish between exogenous (***X***) and endogenous (***Y***) variables:

$$y = \rho Wy + Xb + Y\gamma + u \tag{4}$$

in which ***Y*** is $(n \times r)$ matrix of endogenous variables with $\boldsymbol{\gamma}$ as the corresponding $(r \times 1)$ vector of parameters; and ***u*** is the vector of error terms which is generated as followed:

$$u = R\varepsilon \tag{5}$$

where $\boldsymbol{\varepsilon}$ is a $(n \times 1)$ vector of innovations and ***R*** is a $(n \times n)$ non-stochastic matrix whose elements are not known. Note that the disturbance term ***u*** may be spatially correlated and heteroskedastic. The asymptotic distribution of the instrumental variable estimators of the parameters in (4) depends critically on the quantity: $\Psi = n^{-1}H'\Sigma H$, where $\Sigma = E(\sigma_{ij})$ denotes the variance-covariance matrix of ***u*** and ***H*** is the full matrix of instruments. Following Kelejian and Prucha (2007) SHAC estimator, the $(r,s)^{th}$ estimated element of $\boldsymbol{\Psi}$ is:

$$\hat{\Psi}_{rs} = n^{-1}\sum_{i=1}^{n}\sum_{j=1}^{n} h_{ir}h_{js}\hat{u}_i\hat{u}_j K(x) \tag{6}$$

where $K(x)$ is the Kernel density function. In this study, we use the Parzen-Kernel density function as given by Andrews (1991) :

$$K(x) = \begin{Bmatrix} 1-6x^2+6|x|^3 & for\ 0 \le |x| \le 0.5 \\ 2(1-|x|)^3 & for\ 0.5 \le |x| \le 1 \\ 0 & otherwise \end{Bmatrix}$$

in which x= d_{ij} / d_{max},; d_{ij} is the distance between location ***i*** and location ***j;*** and d_{max} is the bandwidth .

Variable description

The geographical units used in our analysis are *départements* (see Figure in Annex 1), which is an administrative division roughly equivalent to a United Stated county or an English

District. We consider all French continental *départements* [4] except Paris and "*La Petite Couronne*" region. This region, which comprises three *départements*, surrounds Paris, making agricultural activities virtually nonexistent; consequently agriculture data is not available for this area. Descriptive statistics and data source of variables are summarized in Annex 1.

The dependant variable considered in this study is the number of dairy farms in the *département* (y). We include, as Roe et al. (2002) and Larue et al. (2009) have done, the spatial lag of the dependent variable (Wy) to capture location economics within the dairy sector. According to Krugman (1991), local increasing returns could arise from the presence of industry-specific infrastructure and services, which improve the diffusion of information and knowledge among farmers. We expect the spatial lag to be positively related to the dairy farms inventories, so the performance of a single dairy farm improves when other dairy farms are located nearby. Data on the number of dairy farms is provided by the Ministry of Agriculture's Statistical Department (SCEES).

Agglomeration economies can also arise from general economic activities facilitating access to input and output services. Hence, we consider the number of feed processing plants (Feed Plants) as a measure of the availability of protein-rich feed. We hypothesize that the proximity to cattle feed firms influences a dairy farmer's location decision, since the *départements* with a large number of competing firms will probably offer lower prices. On the other hand, animal feed firms may find it advantageous to locate in close proximity to dairy farmers to reduce the average transport costs. Thus, the location of cattle feed cattle manufactures is endogenous. We also measure the accessibility to output markets by including the number of dairy processing plants (Milk Plants). It is expected there are close ties between farmers and dairy processors since milk is a highly perishable product. The number of commercial harbours as well as the local transport infrastructure, as measured by kilometres of road in the *département*, are used as instrumental variables for food and dairy industry location. Data on the industrial sector is obtained from Industry Statistics Studies (SESSI).

Urbanization economies refer to the advantages gained from using a common labour pool, public services and infrastructure, and from having access to market areas for inputs and outputs (Elbert and McMillen, 1999). These positive externalities may lead to urban growth; however, urbanization also implies competition for land and consequently a decrease in the

4 Corsica Island and French Overseas *départements* and Territories are also excluded because they are separated by sea or oceans, implying spatial discontinuity in data.

availability of land for agricultural uses. Therefore, urbanization can affect agriculture in both positive and negative ways. We use *département*'s population as a measure for market size and expect it to positively affect dairy production in a *département*. To measure the availability of local labour we include the *département*'s unemployment rate (Unemployment) and hypothesize that a high unemployment rate will benefit the dairy production since it then will not have to bid labour away from other sectors. Finally, to account for the land competition effect we include the so called artificial areas (Arti-area) which are zones devoted to certain artificial infrastructures - e.g. urban area, substructure, grass lawn, cemetery, etc. In France, the surface area of artificial zones has increased considerably; 60,000 ha of land are converted into artificial area every year at the expense of agricultural and environmental activities (Ifen, 2007). We expect that a large amount of artificial area has a negative effect on the amount of agricultural area, and therefore dairy farms. Population and unemployment data were collected from 2005 Census of Population and the data on artificial areas was provided by the Ministry of Agriculture.

The Common Agriculture Policy (CAP) encourages a better spatial distribution of agricultural production by preventing the desertification of disadvantaged areas, such as mountain and isolated regions, and the concentration of production activities in more competitive areas, which is often associated with environmental pollution (Ben Arfa et al. 2009). To study the influence of Agriculture Policy Support on dairy farms location we include measures of COP[5] Direct Subsidies (ADCOP) and Second Pillar Subsidiaries[6] (ADENV) as well as Young Farmers Premium (YFP), all reported by the Ministry of Agriculture. We expect the *départements* with higher policy support to be favourable to agricultural production, and therefore they will influence dairy farm location. However, the dairy sector is currently facing significant policy changes due to the Luxembourg reform[7] and ongoing WTO[8] (World Trade Organization) trade liberalization negotiations. As a result of recent policy changes, other factors, such as market prices of inputs and outputs, may become decisive in farmers' decisions. To measure the influence of the inputs market, we include the price of rural land (Price Land) reported by Land Management Agencies (SAFER). We can expect cheaper land

[5]COP Subsidiaries: Cereal, oilseed and protein crops

[6] Second Pillar Subsidiaries include environmental subsidiaries (PHAE, MAE, CTE, CAD) as well as compensation to natural disability (ICHN)

[7] Luxembourg reform resulted in a decoupled payment introduction, a significant diminution of dairy product support prices and the expiry of the milk quota system in 2015.

[8] The Doha Development Round is the current trade-negotiation round of the WTO, launched in 2001. Agriculture is placed as major issues of discussion, where negotiation concerns three main areas: export competition, market access and internal support (Vanzetti, 1996)

to attract more farmers, but as price is also an indicator of soil quality, we cannot hypothesize about the sign of this variable. We also measure the role of the output market by including the price of milk in each *département* (Price Milk). Milk quality, final product valorisation, and reputation (quality signs[9] like AOC, PGI and TSG) result in different prices in different *départements*, we therefore hypothesize that high milk price in a *département* have a positive effect on dairy production in this *département*. The data on Milk prices come from the Monthly Dairy Survey conducted by the Livestock Office.

Dairy production activities and other agricultural activities occur in the same areas and can complement each other by sharing common natural and human resources. However, they can also compete with one another for land and other limited inputs. In order to determine the sign and significance of the relation between dairy and other types of farming activities, we consider the number of pig and poultry farms and the number of cattle farms in the *département* as well as in the neighboring *département* ((W+1) PIG and (W+1) Cattle respectively). The farms inventory comes from the 2005 Structure Survey provided by the Ministry of Agriculture.

Concern for the environment is growing rapidly; as a consequence, environmental regulations are also increasingly aimed at reducing the negative impact of livestock production. The EU commission has implemented some manure spreading restrictions and requirements so as to protect areas defined as environmentally vulnerable. The variable used in the model is the surface area, per *département*, defined as vulnerable. These vulnerable zones (Vulnerable-Z) are areas where the water's nitrate content is almost or exceeds 50 mg/m^3. *A priori*, we can expect that these measures will reduce the concentration of livestock production, especially in areas considered environmentally vulnerable. Therefore, we hypothesize a negative effect on dairy farm production and density. At the same time, an area has a higher likelihood of being classified as “vulnerable” when it is characterized by a high concentration of livestock operations and therefore large quantities of manure. Thus, this variable is endogenous; we use the soil quality in the *département*, determined by its limestone, clay and organic carbon contents as an instrumental variable. The percentage of land classified as “Natura 2000[10]” is

[9] AOC: guarantees quality and typicity based on an origin in a local soil or area, PGI: guarantees the link between a product and its geographical origin, TSG: guarantees the traditional character of the product.

[10] Natura 2000 is a European network of (protected areas) natural sites which represent a great heritage value by the fauna and flora they contain. In areas of the network, European Members undertake regulatory and administrative actions to maintain habitats and species involved in a favourable conservation status.

also used as an instrumental variable for the environmental dimension. Environmental data was provided by the French Institute of the Environment (IFEN) and the Scientific Group of Interest for Soil (GIS Sol).

Environmental conditions and topography condition the natural habitat of plants and animals, and therefore agriculture. To measure the influence of climate conditions on dairy farm location, we consider the monthly variation (standard deviation) of rainfall and temperature throughout the year by using the department value of these two variables in the last seventeen years from 1988 to 2005. Dairy farming in the EU has traditionally produced milk on a year-round basis with a feeding system based on pastures and completed by stored forages. We can expect that relatively constant temperatures (Sdev-temp) and rainfall (Sdev-rain) will be favourable to year-round pasture-based milk production, since climate variability throughout the year influences the growth potential of grass and therefore the availability of low-priced food. To account for topographic conditions, we introduced a binary variable that takes the value 1 when the *département* altitude is between 200 and 500 meters; and the value 0 otherwise (Relief). We hypothesize that more dairy farms are located at this level of altitude since lower altitudes are mostly used for crop production and higher altitudes for extensive beef farming. Monthly climate data was provided by the French Climate Institute and altitude data for each *département* was provided by The French Institute for the Environment.

Finally, we include the latitude and longitude location of every *département* as exogenous instruments to account for the spatial configuration of *départements* and as overall instruments for the entire group of endogenous regressors.

Results and Discussion

Table 1 provides 2005 SHAC estimates using different weight matrices, as well as results from OLS and SAR models. Overall, empirical results seem to be robust to the choice of the weight matrix. However, based on the results of the modified Sargan test, which accounts for the heterokedasticity of error term (Fingleton and Le Gallo, 2008), we recommend the use of the time-road weight matrix (SHAC 1/min^2), since in this case the instruments are independent of the residuals (p-value=0.12). Table 2 reports the SHAC elasticity[11] calculated

[11] The elasticity is calculated in a partial equilibrium context so we don't take into account the feedback effect of endogenous variables.

at the mean point. We make a distinction between local elasticity and spatial lag elasticity, the former corresponding to an impact elasticity in time series while the latter is similar to a long run elasticity, taking into account the spatial multiplier (defined as $\frac{1}{1-\rho}$).

Table 1. Parameters estimates in 2005

Variables	OLS		SAR 1/min^2		SHAC Cont		SHAC 1/dist^2		SHAC 1/min^2	
Intercept	-1829.3		-1227.13		-1131.60		-979.44		-1509.11	
Rho			0.46	***	0.65	***	0.57	***	0.63	***
Milk Plants	52.1	***	40.19	***	43.02	***	42.17	***	36.3	***
Feed Plants	23.75	**	20.74	**	24.17	**	18.4	**	22.18	*
Price Milk	168.93	***	116.75	***	91.45	**	106.96	***	122.82	***
Price Land	6.67	**	7.31	***	7.47	***	8.13	**	8.62	***
Population	0.52		0.28		0.33		0.23		0.34	
Unemployment	17.16		6.48		22.6		14.08		1.12	
Arti-area	-11.43	**	-7.57	*	-5.84	*	-6.73	*	-6.7	
(W+1)PIG	0.26		-0.11		-0.13		-0.05		-0.15	
(W+1)Cattle	-0.09		-0.12	**	-0.11	**	-0.13	**	-0.15	**
Sdev-rain	-28.5	***	-21.81	***	-19.96	***	-22.92	***	-22.08	***
Sdev-temp	-339.66	**	-275.33	**	-237.15	**	-288.15	***	-278.13	**
Relief	59.78		54.48		70.71		34.86		68.42	
YFP	22.99	***	21.0	***	15.11	***	17.24	***	21.18	***
ADCOP	-5.07	*	-4.64	*	-0.63		-0.13		0.79	
ADENV	-25.71	***	-18.72	***	-10.64		-13.83	*	-17.36	*
Vulnerable-Z	-5.33		-6.24	*	-11.82	**	-13.38	***	-19.47	***
R^2	0.89		0.91		0.93		0.92		0.9	
Df	73		73		73		73		73	
Sargan p-value					0.0324		0.026		0.12	

*****.**.* : significant at 1. 5. 10 percent**

Table 2. Elasticities calculated at the mean point in 2005

Variables	SHAC Cont		SHAC 1/dist^2		SHAC 1/min^2	
	Local elasticity	Spatial lag elasticity	Local elasticity	Spatial lag elasticity	Local elasticity	Spatial lag elasticity
Milk Plants	0.26	0.76	0.26	0.60	0.22	0.60
Feed Plants	0.1	0.29	0.08	0.18	0.09	0.25
Price Milk	2.41	6.95	2.82	6.54	3.24	8.77
Price Land	0.29	0.83	0.31	0.73	0.33	0.90
Population	0.09	0.26	0.07	0.15	0.10	0.26
Unemployment	0.19	0.56	0.12	0.28	0.01	0.03
Arti-area	-0.26	-0.76	-0.30	-0.70	-0.30	-0.82
(W+1)PIG	-0.04	-0.1	-0.01	-0.03	-0.04	-0.11
(W+1)Cattle	-0.12	-0.36	-0.15	-0.34	-0.18	-0.48
Sdev-rain	-0.73	-2.1	-0.84	-1.94	-0.81	-2.18
Sdev-temp	-1.23	-3.56	-1.50	-3.48	-1.45	-3.92
Relief	0.03	0.07	0.01	0.03	0.02	0.07
YFP	0.84	2.41	0.95	2.21	1.17	3.17
ADCOP	0.03	0.09	-0.01	-0.01	0.04	0.10
ADENV	-0.12	-0.34	-0.15	-0.35	-0.19	-0.52
Vulnerable-Z	-0.29	-0.83	-0.33	-0.76	-0.48	-1.29

Agglomeration variables are significant and positively related to dairy farmer locations. Firstly, the magnitude of rho (ρ= 0.63) suggests a strong spatial dependence, which means that neighboring *départements* are likely to have a similar number of dairy farms. As a result, the presence of a developed dairy sector in the neighboring *départements* will promote dairy activities within the *départements*. It is interesting to note that the impact of "rho" increases when endogeneity is controlled. With respect to the industrial sector, the number of dairy processing plants is positive and significant at 1% level, confirming the mutual and strong relationship between dairy farms and dairy industry and their need to be nearby. The accessibility to feed processing plants is also positive; however it is less significant than for the dairy processing industry. In fact, transport costs of animal feed are lower ((typically one delivery per month and no need for refrigeration systems) than those of milk, which explains the weaker linkage between animal feed industry and dairy farmers.

Market variables are significant for all models, suggesting that input and output prices are major determinants of location of dairy farms. Milk sales represent 68 % of the total income[12] of specialized dairy farms and 53% of the total income of diversified farms (Livestock Office). These numbers confirm the importance of price of milk in the economic viability of farms. Hence, *a priori* it is not surprising to find a higher number of dairy farms in regions with a higher milk price. However, we must be cautious when interpreting this variable since milk price elasticity seems relatively high (Table 2, local elasticity=3.24). In fact, this result may be related to the nature of the variable: milk prices[13] are relatively similar across *départements* (prices only varied from 0.275 to 0.325 Euros/liter for 2005) and so, small changes in prices may artificially inflate the coefficients. As a consequence, discretion must be exercised when assessing the true impact of this variable. The land price variable is also positive, suggesting that in general dairy farms are more likely to be located in areas with high agronomic potentials, providing favourable conditions for forage and cereal production. Moreover, the particularity of the French Dairy Policy is that milk quotas are linked to the land. As a result, a producer who wishes to increase milk production must necessarily acquire or rent additional hectares. Therefore, the quota system may promote competition between dairy farmers for land, causing prices to rise.

Urbanization variables such as population and unemployment rates seem to have little impact on dairy production. The *département*'s population is used here as a proxy for the local demand. However, the market relationship between dairy producers and consumers is not so direct. Dairy products can be distributed in regions other than that where they are produced. With regard to the unemployment rate, French dairy farms, contrary to farms in other EU

[12] The total revenues= agricultural revenues + subsidies. Source: FADN EU, European commission DG AGRI-G3 / Processed by INRA-SAE 2 Nantes 2007.

[13] Source: Monthly Dairy Survey 2005

countries[14], are mainly family structures; they have an average quota of 267,500 kg milk/year; and non-family workers represent only 6 % of the total workforce. Because dairy farms in France are generally tended to by the farmers and their family members, labourers from the outside are seldom needed; the variable is therefore not significant. Finally, the rate of land conversion per year is significant and negative at 10% level, suggesting a real competition for land between agriculture and urbanization. However, this does not seem to be the only source of competition; indeed the presence of other agricultural activities, such as cattle farming, is also a significant and negative factor in the location of dairy farms. The elasticity from land conversion (-0.3) is though higher than from cattle farms location (-0.18).

Environmental variables are significant predictors of *département* dairy production. As expected, consistent rainfall throughout the year as well as stable temperatures have a favourable effect on dairy activity. Besides, the elasticities of these two variables (–0.81 for rainfalls and –1.45 for temperatures) are among the highest. And contrary to our expectations, the relief is not significant. Examining more closely the relationship between the distribution of dairy farms and geography, we observe two areas: a zone of plain and a mountain zone. Our relief variable only takes into account the dairy farms situated on plain; however the mountain zone is not negligible since it represents 14 % of milk production and 20 % of dairy farms. In further research studies, the use of other topographic variables may be considered (i.e., the *département's* average slope or the mountainous surface area per *déparetment*).

With regards to Agricultural Policy Subsidiaries, we note the positive impact of the Young Farmers Premiums. In general, this aid benefits more than 65% of young farmers and represents between 8000 and 22400 €/farm (Livestock Office). This relationship indicates that dairy farmers prefer to locate near agriculturally dynamic areas, characterized by the setting up of young farmers, which reveals an optimistic attitude since the renewal of agriculture is a sign of confidence in the future. *A priori*, CAP Direct Subsidies may be another important factor in maintaining agricultural production and more precisely in promoting the dairy sector since they represent about 74 % of dairy farmers' income[15] (Livestock Office). However, COP Subsidies, which represent half of all direct subsidies, are not significant in our model. In fact, this result corroborates other findings; cereal farms receive the largest share of the COP Subsidies: over 50 %, while dairy farms only get 25 % of the COP Subsidies. Consequently,

[14] i.e., UK has an average quota of 834 650 kg/year, where non-family worker represent 40% of the total AWU. Source: FADN EU and Livestock Office.

[15] Dairy farmer incomes include milk income, beef and veal income, income from vegetal production, subsidies and other incomes.

the impact of this variable on dairy farms' location does not appear in the model since COP Subsidies are for the most part distributed to cereal farms. In addition to the CAP Subsidies, the Second Pillar Subsidies are aimed at promoting an extensive and multifunctional agricultural model and at maintaining agriculture and rural development in disadvantaged areas. The negative sign of this variable indicates that dairy farms are not generally located in these areas, also suggesting the existence of other animal production activities that are more extensive (i.e., beef cattle sector) than dairy production activities.

The restrictions in the animal density as well as the limitations in the level of organic nitrogen (livestock manure) have a negative impact: the larger the surface of the *départements* under environmental restrictions, the fewer the dairy farms *ceteris paribus*. The constraints of the national Code of Good Agricultural Practices are stronger in vulnerable zones. Every farmer must establish an annual provisional fertilizing scheme. The maximum of nitrogen supply coming from the livestock manure is limited to 170 kilograms per hectare per year. Farmers must plant cover crops in winter and plant grass buffer strips along water courses. This necessitates investments to modernize buildings and equipments that were not always anticipated. Thus, dairy farms are not all well prepared for the new challenges. This is especially true for small dairy farms: not only has their number drastically decreased in the last decade, but many of them will probably disappear in the medium term, in particular because of the environmental regulations forcing farmers to upgrade their livestock production facilities to the standards required. (Chatellier et al. 2008). Indeed, the environmental compliance cost would be about 850 Euros per livestock unit which would represent an annual expenditure of 15 to 20 Euros per 1000 litres of milk (Le Gall et al. 2004). However, to determine the real effect of these environmental measures, further research is needed to study their impact on other animal breeding activities such as pig and poultry production. Moreover, an analysis at the scale of a *canton* or *commune*[16] will reveal the impact of these measures more accurately.

Table 3 presents the estimates for the 1995 data. In contrast to 2005 model, results are significantly different. The Wald test that the coefficients are statistically different between

[16] In France metropolitan, we find 95 *départements*, 337 *arrondissements*, each encompassing a number of cantons and finally 36,000 communes.

time periods yields a p-value of 0.0976 and provides some evidence that a structural change occurred between 1995 and 2005.

Table 3. Parameters estimates in 1995

Variables	OLS	SAR	SHAC Cont	SHAC 1/dist^2	SHAC 1/min^2
Intercept	2377.68	2457.23	3549.99	3710.88	880.45
Rho		0.41 ***	0.68 ***	0.57 ***	0.68***
Milk Plants	100.25 ***	88.34	96.56 ***	88.38 **	48.2
Feed Plants	-6.15	-7.39	10.68	6.9	13.3
Price Milk	33.76	-6.59	-76.38	-45.14	46.31
Price Land	6.07	8.11	8.65 *	10.44 *	10.58 **
Population	0.31	0.08	-0.27	-0.4	0.25
Unemployment	1.22	-5.03	12.6	-8.03	-25.19
Arti-area	-12.43	-8.38	-3.54	-3.21	-4.17
(W+1)PIG	0.07	-0.27	-0.34	-0.38	-0.77 **
(W+1)Cattle	0.15 *	0.07	-0.01	-0.02	-0.0004
Sdev-rain	-19.03 *	-11.19	-7.48	-10.67	-4.68
Sdev-temp	-468.05 **	-386.46 **	-310.69	-417.71 **	-444.95 *
Relief	-74.8	-95.54	-52.65	-105.35	95.00
YFP	20.82 ***	19.52 ***	12.53 ***	15.32 ***	19.47 ***
ADCOP	-5.55	-4.62	-1.84	-4.16	-8.21 *
ADENV	-76.61 ***	-62.34 ***	-35.36	-43.44	-39.65
Vulnerable-Z	-11.48 *	-11.48	-11.59	-8.73	-2.4
R^2	0.88	0.89	0.92	0.91	0.89
Df	73	73	73	73	73
Sargan p-value			0.04	0.055	0.06

*****.**.* : significant at 1. 5. 10 percent**

The location of dairy farms in 1995 seems to be well explained by spatial externalities specific to the dairy production sector. Indeed, the presence of dairy clustering (represented by rho=0.68) suggests the development of scale economies favourable to dairy farming. Moreover, *départements* where young farmers are active (YFP) are associated with more dairy farms as found also in 2005. On the contrary, the role of market signals and the accessibility to the agro-industry are not determinants of dairy location in 1995. In 1995 the milk support price was more important and farmers did not have to worry about prices because they had guaranteed prices. In fact, only land price is significant and positively related to the number of dairy farms per *département*. With regard to the role of the industrial sector in 1995, a higher number of processing plants increase the accessibility to inputs and outputs. However, the decrease in the number of processing firms in the last 10 years and their heterogeneous distribution in space tend to increase transport costs, and as a result had become an important factor in 2005. Finally, the Market Trade Liberation and the reduction in

Agricultural Subsidies promote the survival and development of farms presenting better conditions in terms of climate and market competitiveness. In addition, sustainable development is becoming an important condition due to the growing concern for the environmental and to the implementation of environmental measures. Other factors may be different from those chosen for the 2005 model, and could better explain location of dairy farms. We think for example of performance and access to techniques and efficient equipments.

Conclusion

This paper contributes to the literature by providing insight into the spatial structure of the French dairy sector, helping us gain a better understanding of the agglomeration and dispersion forces that influence the location of dairy farms in France in 1995 and 2005. In addition to traditional determinants, we have focused on spatial agglomeration externalities as well as the impact of agricultural policy subsidies and environmental regulations. We have used a non-parametric heteroskedasticity and autocorrelation consistent (HAC) parameter covariance estimator proposed by Kelejian and Prucha (2007), which enables us to handle simultaneous equations and spatial endogeneity.

The implementation of the dairy quota system by the French authorities has limited the geographic concentration of milk production in those *départements* with comparative advantages. However, the number of dairy farms has not stopped decreasing and the rate of decrease is not the same in all *départements*. Western France now accounts for half of the national production of milk. In fact, we infer that there has been a non-arbitrary structural change in dairy production that has had important consequences on the agricultural landscape. The market signals, the Agricultural Policy, and the spatial agglomeration externalities are determinants of this transformation.

With regard to agglomeration externalities, the number of dairy farms in the neighboring *départements* has a positive influence on the number of dairy farms in the *département*. This indicates that dairy farms benefit from sharing industry-specific infrastructure and services, improving as a result the performance of each individual farm when other dairy farms are located nearby. Agglomeration economies also arise from the development of the industrial sector close to agricultural areas, which improves access to the input and output markets. In fact, we find that market access variables become increasingly important determinants of the location of dairy farms. These agglomeration forces promote livestock production activities in competitive areas, but this concentration is often associated with environmental problems. In order to address this, the EU has implemented environmental regulations that aim at limiting concentration, ceteris paribus.

We have found that a structural change took place between 1995 and 2005; Indeed the impacts of the various factors of location changed during that period. This can be attributed, to some extent, to the 2003 reform of the European Common Agricultural Policy (CAP). This policy change has encouraged farmers to adapt their production to market demands. This is coherent with our results since market prices and market accessibility have become key determinants of dairy production. For example, while milk prices were not significant factors in 1995, they were, in 2005, essential determinants of the location of dairy farms.

Acknowledgements

This work has been supported by the CNIEL, Crédit Agricole, GROUPAMA and SEPROM. The views defended here are the authors' views and not necessary those of these organizations.

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Annexes

Annexe 1. Summary statistics

Variables	Description	Mean	Std.Dev	Min	Max	Source
Dependent Variable						
Y	Number of dairy farms in the *département*	1095.07	1259.22	1.48	5673.24	SCEES[1]
Independent Variables						
WY	Number of dairy farms in the neighboring *départemens*					
Price Milk	Price of Milk	28.88	1.21	27.43	31.59	Livestock Office [2]
Price Land	Price of Land	42.42	16.36	16.15	121.75	SAFER
Population	Population	308.75	227.94	37.98	1328.83	INSEE[3]
Unemployment	Unemployment rate	9.42	1.85	5.80	14.60	INSEE[3]
Arti-area	Surface of artificial Land (land competition)	49.44	20.82	8.32	119.68	SCEES[4]
(W+1)Pig	Number of Pig in the *département* as well neighboring *département*	303.42	704.05	0.00	3781.00	SCEES[1]
(W+1)Cattle	Number of cattle in the *département* as well neighboring *département*	1292.15	1337.84	0.00	5075.00	SCEES[1]
Sdev-rain	Monthly variation of rainfall (standard deviation)	39.99	9.85	25.46	70.91	Climate Institute
Sdev-temp	Monthly variation of temperature (standard deviation)	5.70	0.62	3.63	6.68	Climate Institute
Relief	*Département* altitude (Dummy variable)	0.39	0.49	0.00	1.00	IFEN[5]
YFA	Young Farmers Allocations	60.54	37.69	0.00	174.00	Livestock Office
ADCOP	COP Subsidies	50.93	37.59	0.00	148.19	SCEES[6]
ADENV	Environment Subsidies	12.09	13.15	0.40	75.08	SCEES[6]
Endogenous Variables						
Milk Plants	Dairy processing plants	7.01	7.14	0.00	33.00	SESSI[7]
Feed Plants	Feed processing plants	4.81	7.60	0.00	57.00	SESSI[7]
Vulnerable-Z	Number of *communes* per *département* classed as environmentally vulnerable zones	26.79	23.87	0.00	82.00	IFEN[5]
Instrumental Variables						
Harbours	Commercial harbours	0	1	0	3	SESSI[7]
Roads	Local Transport infrastructure	42	15	5	79	
Natura 2000	Share of Land classed as Natura 2000	12	10	1	49	IFEN
Soil	Soil quality					IFEN
	% limestone	78	90	0	457	
	% clay	211	53	97	353	
	% organic carbon	17	6	10	47	

1.Structure Survey 2005 2. Dairy Survey, 3. Census of Population, 4. TERUTI Survey, 5. French Institute for Environment. 6.Agriculture Public Support. 7. Annual Business Survey

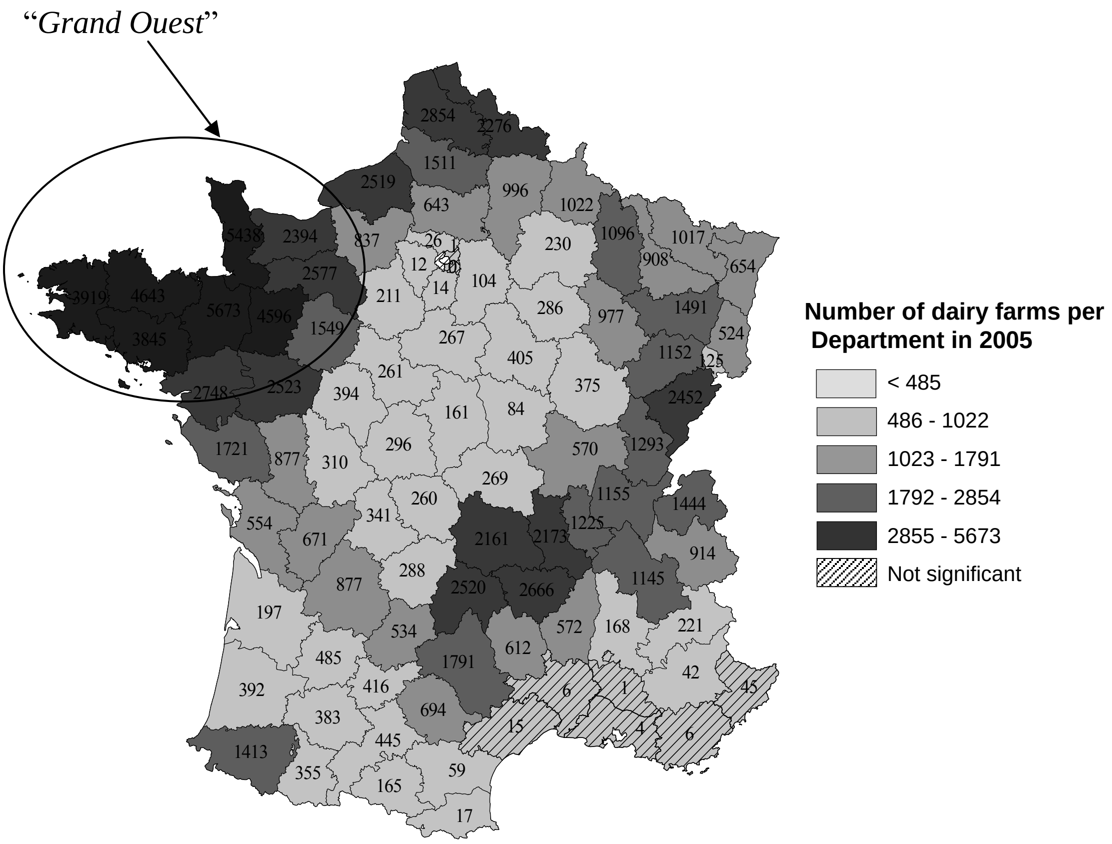

Figure 1: Number of dairy farms per *département* in France