Spatial Structure of the French dairy sector: a spatial HAC estimation

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Abstract

The French dairy sector has been undergoing significant changes both in term of scale and structure over the past several decades. There has been a general tendency toward fewer, yet larger operations, increased concentration, and consolidation of production. These changes become crucial because of the decrease of subsidies for the dairy and livestock sectors and the increase of public concerns about environmental quality degradation due to location of key production regions in environmentally sensitive areas. Indeed, the three traditional dairy producing regions, alone account for 47% of the national production, with 11 billion liters of cow's milk, and retain the greatest number of farms (42% in 2005).

This paper contributes to the literature by offering an insight in the spatial structure of the French dairy sector, allowing 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 focus on spatial agglomeration externalities as well as the impact of agricultural policy subsidies and environmental regulations. We use a non-parametric heteroscedasticity and autocorrelation consistent (HAC) parameter covariance estimator proposed by Kelejian and Prucha (2007) that allows us to handle simultaneous equations and spatial endogeneity.

Key words: Dairy sector, Spatial Econometrics, Agglomeration, Policy Support, Environmental pollution

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 becomes less important over time. In particular, the 2003 Luxembourg Agreement of the CAP has strongly modified the structure of dairy subsidies by simultaneously diminishing milk support prices and implementing instead direct payments. Therefore, the price of milk is less regulated which acts to increase its inherent volatility due to the inelastic nature of demand and the rigidity of the production cycle. As a result of these policy reforms, dairy farms are more than ever encouraged to adapt their production towards market signals.

Nowadays, the dairy sector is facing 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 63 %, from 268 563 farms in 1988 to only 99 374 in 2005. In fact, the reduction 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 adoption of more intensive production systems and so, the gain in scale economies. Moreover, a tremendous increase in milk yield per cow has occurred 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 across geographical locations. The principal productive area, named the "Grand Ouest" and composed of Bretagne, Pays de la Loire and Basse-Normandie, alone accounts for 47 % of the national production with 11 billion liter of cow's milk and represents the biggest concentration of dairy farms (42 % of the total number of dairy farms in 2005). These regions have followed a highly industrialized pattern of production with herd sizes larger than the national average and they also show a slower rate of disappearance of dairy farms. Indeed, dairy farms from West France, generally more competitive in terms of production milk cost, collection and transport cost, have been able to better adapt to this new economic environment. However, it has not been the case for other traditional dairy regions, located in mountain areas, which represent the non-negligible 20 % of French dairy farmers. In fact, there is an important gap in production structure between mountainous and other French regions: a farm located in the mountains produces on average 175 000 litres of milk against 276 000 litres produced by a farm located in the plain.

Moreover, the production cost of milk in the mountains is 4 to 15 % higher and collection costs represent 12 € extra per 1000 litres of milk. As a consequence, these regions, less competitive and thus highly dependent on policy subsidies, are more troubled by 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 know today may change. Firstly, the retirement of dairy production in disadvantaged areas, such as mountain and isolated regions, may lead to social problems. Indeed, agricultural activities in these areas represent 10 % of employment. Moreover, dairy activity plays an important role in maintaining the density of rural and open areas, contributing as well to environmental protection (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 contributing significantly to air and water pollution. Following the increasing awareness about environmental threats, the UE has started to implement new environmental regulations in order to reduce the negative impacts of livestock production (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) have agricultural policies and environmental regulations had an impact on dairy farm location? ii) Is spatial clustering an important feature of the dairy sector? iii) What determinants influence structural changes? In order to answer these questions, we use an econometric model of the number of dairy farms at the departmental level in France for the years 1995 and 2005. We estimate our model using the recently developed methodology of Kelejian and Prucha (2007). The methodology is a 2SLS spatial model, which provides us with a non-parametric heteroscedasticity and autocorrelation consistent (HAC) estimators of the parameter variance-covariance (VC) matrix.

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

Literature review

Few researchers are interested in the spatial distribution of agricultural production. Gillmor (1987) used a geographical approach to analyse the concentration of enterprises and spatial change in agriculture of the Republic of Ireland. Abdalla et al. (1995) have introduced the factors influencing location decisions and regional shifts. Osei and Lakshminarayan (1996) looked at the determinants of dairy farm location in the US with a main focus 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) are the first who 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 with a particular interest 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's assumed that a farmer's land allocation decisions depend on the prices of key inputs facing that farmer. In dairy production key inputs include feed. Another important factor is the milk price. This assumption is based on basic profit motives in microeconomic theory. However prices for agricultural commodities are normally based on their relative distance from key markets. In general when a commodity is produced further from a market it receives a lower price. This is how the location of a farm affects its prices. If the local prices of commodities are generally available, distance from market may not need to be incorporated in a model since the distance should be part of the local price (Brewin 2004).

According to Blair and Premus (1993) location theory in economics evolved from a simple minimization of transportation cost integrating two locational 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, quality of life factors and other regional differences were integrated into increasingly complex models of the firm location process.

There have been many studies of why specific types of firms locate in different regions, including Barkley and Keith (1991) and Bartik (1989). Various factors affect the choice of firm location. Most of the studies in this area ignore local natural endowments. They instead look at community infrastructure, tax levels and available moving incentives.

The omission of local resources could be due to difficulties in measuring the endowments or the complex structure of industries related to natural endowments, such that theoretical relationships are difficult to confirm.

Agriculture makes use of local natural endowments that are fairly well measured. The reasons agricultural firms might locate in a region include the availability of good farm land, rainfall and perhaps the availability of livestock, availability of labor, availability of materials and services that are provided to farms. Some of the findings of previous studies, where specific factors were reported and ranked, are that farms were also likely to consider environmental and policy factors.

Approach

In this study, we follow the comprehensive behavioral model of dairy farm location as developed by Isik. 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, since economic activities may interact across space, as well as the presence of endogenous variables due to the simultaneous relationships. 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 habitually been disregarded. “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 that allows us to analyse both endogeneity and simultaneous spatial interaction. This procedure develops a non parametric heteroscedasticity 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:

$$y = Xb + \varepsilon \quad (1)$$

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, the equation (1) is extended through the addition of a spatially lagged dependent variable ($\boldsymbol{Wy}$):

$$y = \rho Wy + Xb + \varepsilon \quad (2)$$

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 $\boldsymbol{i}$ and an observation in location $\boldsymbol{j}$, and so the $\boldsymbol{W}$ 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 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, following most of empirical studies (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 centroids of locations ***i*** and ***j*** and $\boldsymbol{D}$[1] is the critical cut-off. In our application ***D*** is equal to 115 km since it is the minimum distance that guarantees connections between all departments. Each matrix is row standardized so that it is relative and not absolute distance that matters. However, these matrices assume equal importance to all departments located at a same geographical distance without taking into account the economic potential of the departments or their accessibility (Keilbach 2000, Dall'Erba 2004 b, Virol 2006). To better represent real spatial interactions, we also use time-road distance where ***D*** is 90 minutes. 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 leads to the inconsistency of SAR model.

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

$$y = \rho W y + X b + Y \gamma + u \tag{4}$$

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 heteroscedastic. 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 :

[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.

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

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

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

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

Variable description

The geographical units used in our analysis are departments[2], which is an administrative division roughly analogous to a United Stated county or an English District. We consider all French continental departments[3] except Paris and "*La Petite Couronne*" region. This region, composed by three departments, surrounds Paris city making agricultural activity virtually nonexistent, consequently agriculture data is not available for this area. Descriptive statistics and data source of variables are summarized in Annexe 1.

The dependant variable considered in this study is the department number of dairy farms (y). We include, as Roe et al. (2002) and Larue et al. (2009), the spatial lag of the dependent variable (Wy) to capture location economics within the dairy sector. Following Marshall (1977), local increasing returns could arise from the presence of industry-specific infrastructure and services, which improve diffusion of information and knowledge through 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 Agriculture Ministry Statistical Department (SCEES).

[2] France has 100 departments which are grouped into 22 metropolitan and four overseas regions. All regions have identical legal status as integral parts of France.

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

Agglomeration economies can also arise from general economic activity facilitating access to input and output services. Hence, we consider the number of feed processing plants as a measure of the availability of protein-rich feed. We hypothesize that the proximity to feed cattle industry has an impact on the location of a dairy farmer, since farmers are typically associated with technical advisors. In addition, departments with a larger number of competing firms will probably offer lower prices. On the other hand, feed industry may have an interest in being close to dairy farmers to reduce the average transport costs. The location of the feed cattle industry is thus endogenous. We also measure the accessibility to output markets by including the number of dairy processing plants. It is expected there are close ties between farmers and processors since milk is a very perishable product. The number of commercial harbours as well as the local transport infrastructure, as measured by kilometres of road in the department, are used as instrumental variables for food and dairy industry location. Data on the industrial sector is obtained from Industry Statistics Studies (SESSI).

Urbanisation economies describe the productive advantages from sharing a common labor pool, public services and infrastructure, and from accessibility to market areas for inputs and outputs (Elbert and McMillen, 1999). These positive externalities may lead to urban growth, however, urbanisation also implies competition for land consequently decreasing the availability for agricultural uses. In addition, conflicts between residential population and farmers may emerge from sharing urban transport, air and water externalities (Abdalla et al.,1995). Therefore, urbanization can affect agriculture in both positive and negative ways. We use departmental population as a measure for market size and expect it to positively affect dairy production in a department. To measure the availability of local labor we include the department unemployment rate and hypothesize higher unemployment will benefit dairy production since it will not have to bid labor away from other sectors. Finally, to account for the land competition effect we include the rate of land conversion per year and expect a negative effect on dairy farms localisation. Population and unemployment data are collected from 2005 Census of Population and land conversion data is reported by Agriculture Ministry.

The Common Agriculture Policy (CAP) has favoured a better spatial distribution of agricultural production by preventing desertification of disadvantaged areas, such as mountain and isolated regions, and by avoiding higher production concentration 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[4] (ADCOP) and Second Pillar Subsidiaries[5] (ADENV) as well as Allocations for Young Farmers (DJA), all reported by Agriculture Ministry. We expect departments with higher policy support to be favourable to agriculture production, thus dairy farm location. However, the dairy sector is facing today significant policy changes due to Luxembourg reform[6] and ongoing WTO[7] (World Trade Organisation) trade liberalisation negotiations. As a result of recent policy changes, other factors, such as market prices of inputs and outputs, may became decisive in farmer decisions. To measure the influence of the inputs market, we include the price of rural land reported by Land Management Agencies (SAFER). We can expect cheaper land to attract more farmers, but as price is also an indicator of soil quality, we do not forward a hypothesis on the sign of this variable. We also measure the impact of the output market by including milk producer department prices. Milk quality, final product valorisation, and reputation (quality signs[8] like AOC, PGI and TSG) make prices differ between departments, we hypothesize therefore that higher department prices will have a positive effect on dairy production and intensity. Milk prices are collected from the Monthly Dairy Survey reported by Livestock Office.

Dairy production takes place in the same areas as other agriculture production; these other activities can act as complementary ones promoting the dairy sector due to sharing common natural and human resources. However, they can also act as substitute activities competing with the dairy sector for land and other limited inputs. In order to measure the sign and importance of the relation between dairy and other types of farming, we consider the number of pig and cattle farms including as well neighbouring department farms. The farms inventory is obtained from 2005 Structure Survey provided by Agricultural Ministry.

Environmental concerns are growing fast; as a consequence environmental regulations are also increasingly aimed toward reducing the negative impact of livestock production. The EU commission implemented some restrictions and requirements for spreading of manure in

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

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

[6] 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.

[7] 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)

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

locations defined as environmentally vulnerable areas. The variable used in the model is the surface, by department, which is defined as vulnerable. These vulnerable zones (ZV_03) are areas where the water content of nitrate approaches or exceeds 50 mg/m3. *A priori*, we can expect that these measures will reduce dairy production in areas where livestock agglomeration is important. Therefore, we hypothesize a negative effect for dairy farm production and density. At the same time, we also have a greater likelihood of a zone being classified as vulnerable when livestock manure is high due to animal concentration. This variable is thus endogenous, we use the soil quality in the department, measured by the share of limestone, clay and organic carbon, as instrument. The share of land classed as "Natura 2000[9]" is also used as an instrument for the economic environmentally measure. Environmental data is collected from the French Institute for Environment (IFEN) and the Scientifc Group of Interest for Soil (GIS Sol).

Environmental conditions and topography define the natural habitat for plants and animals, influencing also agricultural activity. To measure the influence of climate conditions on dairy farm location, we consider the variation of rainfall and temperature throughout the year by including the mean department value of these two variables in the last seventeen years (from 1988 to 2005). Dairying 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 seasonal temperature and rainfall will be favourable to year-round pasture-based milk production, since climate variability throughout the year influences the growth potential of grass and hence the accessibility to low-priced food. To account for topographic conditions, we introduced a binary variable that takes the value 1 when the department altitude is between 200 and 500 m; otherwise the value is 0. 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 cattle farms. Monthly climate data is obtained from French Climate Institute and altitude department is provided by The French Institute for Environment.

Finally, we include the latitude and longitude location of every department as exogenous instruments to account for the spatial configuration of departments and serve as well as overall instruments for the entire group of endogenous regressors.

[9] Natura 2000 is a European network of 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.

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. Based on results of the modified Sargan test, which accounts for the heterocedasticity of error term (Fingleton and Le Gallo 2008), we recommend however 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). The Table 2 reports the SHAC elasticity[10] estimated at the mean point. We make a distinction between local elasticity and spatial lag elasticity, the first one corresponds to an impact elasticity in time series while the second one 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	
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	
Land_press	-11.43	**	-7.57	*	-5.84	*	-6.73	*	-6.7	
(W+1)Pork	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	
DJA	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	*
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	*
ZV	-5.33		-6.24	*	-11.82	**	-13.38	***	-19.47	***
Correlation	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**

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

Table 2. Elasticity estimates 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
prix_milk	2.41	6.95	2.82	6.54	3.24	8.77
prix_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
Land_press	-0.26	-0.76	-0.30	-0.70	-0.30	-0.82
(W+1)Pork	-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
DJA	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
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
ZV	-0.29	-0.83	-0.33	-0.76	-0.48	-1.29

Market variables are significant for all models, suggesting that input and output prices have major roles as determinants of dairy location. Milk sales represent 68 % over the total revenues[11] in specialized dairy farms and 53% for diversified farms (Livestock Office). These numbers confirm the importance of milk price in the economic viability of farms. Hence, *a priori* it is not surprising to find a higher number of dairy farms located in regions with a higher milk price. However, we must be prudent in the interpretation of 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[12] are finally quite similar among departments (department price vary only between 0.275 to 0.325 euros/litre for 2005) and so, small changes in prices may inflate artificially the coefficients. As a consequence, some discretion is advised in assessing the true impact of this variable. The land price variable is also positive, suggesting that in general dairy production is more likely located in areas of high agronomic potential providing favourable conditions to forage and cereal production. Moreover, the particularity of French Dairy Policy is that milk quotas are linked to the land. As a result of this measure, 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 thus causing price to rise.

Urbanization variables such as population and unemployment rate seem not to have a great impact on dairy production. Departmental population is used here as a proxy for the local

[11] The total revenues= agricultural revenues + subsidies. Source: FADN EU, European commission DG AGRI-G3 / Processed by INRA-SAE 2 Nantes 2007.
[12] Source: Monthly Dairy Survey 2005

demand. However, the market relationship between dairy producers and consumers is not so direct. In fact, milk plants process most of dairy production so down stream, dairy products can be distributed widely. Looking at the unemployment rate, French dairy farms, on the contrary to other countries in the EU[13], are mainly family structures, having an average quota[2] of 267 500 kg milk/year, where non-family workers represent only 6 % of the total Annual Work Unit. As a result from the low need of workers, it is not surprising that the labour availability has no influence in French dairy sector. Finally, the rate of land conversion per year is significant and negative in most of the models, suggesting a real competition for land between agriculture and urbanisation. However, it seems not to be the only source of competition, the presence of other agriculture production, like cattle farms, has also a significant, negative association with dairy location. The elasticity from land conversion (-0.3) is though higher than from cattle farms location (-0.18).

Environmental variables are significant predictors of department dairy production. As expected, consistent rainfall throughout the year as well as a stable temperature have a favourable effect on dairy activity. Besides, the elasticities of these two variables (–0.81 for rainfalls and –1.45 for temperature) are among the highest ones. On the contrary, the relief is not significant in spite of our expectations. Regarding in more detail the relationship between the distribution of dairy farms and geography, we can observe two areas: a zone of plain and other of mountain. Our variable relief only takes into account dairy farms located in plain, however the area on mountain is not negligible since it represents 14 % of milk production and 20 % of dairy farms. In further researches, the use of other topographic variables may be considered (i.e., the department average slope or the mountainous surface by department).

With regards to Agricultural Policy Subsidiaries, we note the positive impact of the Allocations for Young Farmers. In general, this aid benefits more than 65% of young farmers and represents from 8000 to 22400 €/farm (Livestock Office). This relationship indicates the preference of dairy farmers to locate near agriculturally dynamic areas, characterized by the setting up of young farmers, which reveals an optimist attitude since the renewal of agriculture is a sign of the trust in future. *A priori*, CAP Direct Subsidies may be another important factor to maintain agriculture and more precisely promote the dairy sector since

[13]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.

they represent about 74 % of dairy farmer income[14] (Livestock Office). However, COP Subsidies, which correspond for dairy farmers to half of Direct Subsidies, are not significant in our model. In fact, this result corroborates the reality: cereal farms receive the biggest part of COP Subsidies, more than 50 %, while dairy farms only get 25 % of COP Subsidies. Consequently, the impact of this variable on dairy location does not appear in the model since COP Subsidies distribution is mainly explained by cereal farms location. Completing CAP Subsidies, the aim of Second Pillar Subsidies is to promote an extensive and multifunctional agricultural model and to maintain agriculture and rural development in disadvantaged areas. The negative sign of this variable indicates that in general dairy farms are not located in these areas, suggesting as well the existence of other animal productions which are more extensive (i.e., beef cattle sector) than dairy production.

Agglomeration variables are significant and positively related to dairy farmer locations. Firstly, the magnitude of rho ($\rho = 0.63$) suggests a strong spatial dependence, which means that neighbouring departments are likely to have a similar number of dairy farms. As a result, the presence of a developed dairy sector in the neighbouring departments will promote dairy activity within the department. It is interesting to note that the impact of "rho" increases when endogeneity is controlled. With respect to industry, a large number of dairy processing plants reflects the presence of an important complement to dairy production, confirming the mutual dependence. The accessibility to feed processing plants is also positive, however it is less significant than for the dairy processing industry. In fact, transport costs are lower (typically one delivery per month and no need of refrigeration systems) making the relationship between the feed industry and dairy farmer not so strong

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 department under environmental restrictions, the fewer the dairy farms *ceteris paribus*. However, to determine the real effect of these environmental measures, further research may study their impact in regard to other animal sectors such as hog and poultry production. Moreover, the analysis in a canton or commune[15] scale will be more precise to reveal the local impact in location and agricultural production of areas defined as environmentally vulnerable.

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

[15] In France, we find 95 departements, 337 arrondissements, each encompassing a number of cantons and finally 36,000 communes.

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 time periods yields a p-value of 0.0976 and provides some evidence that a structural change has 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
prix_milk	33.76	-6.59	-76.38	-45.14	46.31
prix_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
Land_press	-12.43	-8.38	-3.54	-3.21	-4.17
(W+1)Pork	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
DJA	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
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
ZV	-11.48 *	-11.48	-11.59	-8.73	-2.4
Correlation	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

The location of dairy farms in 1995 seems to be well explained by spatial externalities specific to dairy production sector. Indeed, the presence of dairy clustering (represented by rho=0.63) suggests the development of scale economies favourable to location of dairy farms. Moreover, departments where young farmers are active (DJA) 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 fact, only land price is significant and positively related to the number of dairy farms by department. With regard to the role of the industrial sector in 1995, a higher number of processors improve the accessibility to inputs and outputs. However, the strong diminution of firms in the last 10 years period and the heterogeneous allocation in space make transport costs rise, becoming 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 also an important condition due to the growing environmental concerns as well as the implementations of environmental measures.

Conclusion

This paper contributes to the literature by offering an insight in the spatial structure of the French dairy sector, allowing 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 focus on spatial agglomeration externalities as well as the impact of agricultural policy subsidies and environmental regulations. We use a non-parametric heteroscedasticity and autocorrelation consistent (HAC) parameter covariance estimator proposed by Kelejian and Prucha (2007) that allows us to handle simultaneous equations and spatial endogeneity.

The implementation of the dairy quota system by French authorities has limited the geographic concentration of milk production in those departments with comparative advantages. However, the number of dairy farms has not stopped decreasing (- 33.5 % dairy farms less between 1995 and 2005) and the diminution is not homogeneous between departments. The West of France now accounts for half of the milk national production. In fact, we infer a structural change in dairy production, which is not arbitrary and has important consequences in the agricultural landscape. The market signals, the Agricultural Policy, and the spatial agglomeration externalities are determinants of this transformation.

With regard to the agglomeration externalities, the number of dairy farms in the neighbouring departments has a positive influence within the dairy dynamic of the department. 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. Agglomerations economies also arise from the development of the industrial sector next to agricultural areas, which improves the access to the input and the output market. In fact, we find that market access variables become increasingly important to explain the location of dairy farms. These agglomeration forces promote the livestock activity in competitive areas, but this concentration is often associated with environmental problems. In order to address this, the EU has implemented environmental regulations that act to diffuse concentration, ceteris paribus.

We found that a structural change has taken place in the pattern of dairy farm numbers between 1995 and 2005. To some extent this may be attributed to the reform of European Common Agricultural Policy (CAP) in 2003. This policy change encourages farmers to choose and adapt their production towards the needs of the markets. This schema is indeed coherent with our results since market prices and market accessibility are become more dominant as determinants of dairy production. For example, milk prices were not significant in 1995 while in 2005 they constitute an essential determinant for explaining the location of dairy farms.

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Annexes

Annexe 1. Summary statistics

Variables	Mean	Median	Std.Dev	Min	Max	Source
Dairy_farms	1095.07	591.89	1259.22	1.48	5673.24	SCEES[1]
Prix_milk	28.88	29.06	1.21	27.43	31.59	Livestock Office [2]
Prix_land	42.42	37.64	16.36	16.15	121.75	SAFER
Population	308.75	263.60	227.94	37.98	1328.83	INSEE[3]
Unemployment	9.42	9.20	1.85	5.80	14.60	INSEE[3]
Land_press	49.44	48.08	20.82	8.32	119.68	SCEES[4]
(W+1)Exp_Gra	303.42	27.50	704.05	0.00	3781.00	SCEES[1]
(W+1)Exp_Bov	1292.15	801.38	1337.84	0.00	5075.00	SCEES[1]
Sdev_rain	39.99	37.72	9.85	25.46	70.91	French Climate Institute
Sdev_temp	5.70	5.69	0.62	3.63	6.68	French Climate Institute
Relief	0.39	0.00	0.49	0.00	1.00	IFEN
DJA	60.54	52.00	37.69	0.00	174.00	Livestock Department
ADCOP	50.93	44.99	37.59	0.00	148.19	SCEES[5]
ADENV	12.09	7.05	13.15	0.40	75.08	SCEES[5]
Milk_Plants	7.01	5.00	7.14	0.00	33.00	SESSI[6]
Feed_Plants	4.81	3.00	7.60	0.00	57.00	SESSI[6]
ZV	26.79	22.28	23.87	0.00	82.00	IFEN

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