Evolution of the disparities in agricultural productivity across European regions. An analysis of the distribution dynamics

Abstract:

This paper examines the evolution of the European agricultural productivity distribution on the hypothesis of persistent differences in productivity over time. We use the *Cambridge Econometrics European Regional Database* on a sample of 125 EU-regions from 1985 to 2004. Density functions, Markov chains and stochastic kernels are combined to analyse the dynamics of the productivity distribution. Our results suggest no evidence on productivity convergence. Regional disparities across the European agricultures are large and persistent. Moreover, the highest levels of persistence are concentrated in the upper and lower productivity classes. We find that agricultures with similar structural characteristics (economic and territorial dimension, characteristics of the labour force, pattern of specialization) tend to converge in productivity. The main result is that the diversity of structural patterns configures a sector where the differences in productivity tend to remain.

Keywords: agricultural productivity, European regions, convergence, density function, Markov chains, stochastic kernels.
JEL code: R11, Q10

Resumen:

El trabajo analiza la evolución de la distribución de la productividad agraria Europea bajo la hipótesis de la persistencia de las diferencias en los niveles de productividad a lo largo del tiempo. Los datos proceden de la base europea de datos regionales de Cambridge Econometrics para un conjunto de 125 regiones de la UE-15 en el periodo 1985-2004. Para analizar la dinámica de la distribución se combina el análisis de las funciones de densidad, las cadenas de Markov y los kernels estocásticos. Los resultados no aportan evidencia a favor de un proceso de convergencia en productividad entre las regiones europeas. Las disparidades regionales entre las agriculturas son amplias y persistentes. Asimismo, los mayores niveles de persistencia se dan en los extremos de la distribución. Las agriculturas que comparten características estructurales similares (dimensión económica y territorial, características de la mano de obra, empleada, patrón de especialización) tienden a converger en productividad. El resultado principal es que la diversidad de patrones estructurales configura un sector en el que las diferencias en productividad tienden a perpetuarse.

Palabras claves: productividad agraria, regiones europeas, convergencia, funciones de densidad, cadenas de Markov, kernels estocásticos
Clasificación JEL: R11, Q10

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1. Introduction

Regional disparities are due to the diversity of productive structures. In this sense, the EU agricultural sector is one of the most heterogeneous. This implies huge productivity and income differences among European agricultures. Because of that, the reduction of disparities within the sector has been a great concern for economic policy makers since the beginning of the European integration process.

In the traditional theoretical approaches (neoclassical models), regions involved in a liberalization and integration process converge to the same levels of productivity. The reinforcement of the Common Market and the implementation of a Common Agricultural Policy (hereinafter CAP) should have resulted in a greater convergence in agricultural productivity and efficiency. The farmers' effort to compete in the European market in the best conditions could explain this behaviour. Nevertheless, after nearly fifty years since the beginning of the CAP, huge differences in productivity persist. Natural conditions, climate, geographical situation, specialization pattern, dimension of the holdings, proximity to the consumption centres, innovation capacity or endowment of productive factors (land, labour, physic and human capital), highlight the existence of important disparities in the European agricultural sectors. These aspects condition the possibilities of endogenous development of territories in such a way that they determine the unequal evolution of the productivity.

This paper aims to analyse the dynamics evolution of the regional agricultural productivity in order to find out whether convergence takes place and whether the existence of different structural patterns conditions the results. Productivity is measured as the real Gross Value Added (hereinafter GVA) at basic prices per worker for a set of 125 EU-15 regions in the period 1985-2004. Employment and production data are drawn from the *Cambridge Econometrics European Regional Database* which complements REGIO database from Eurostat.

The limitations of the methodology traditionally used in most convergence studies (β-convergence equations and σ-convergence) lead to an analysis of distribution dynamics. Following Quah (1993, 1996a, 1996c) nonparametric approaches, - density function, Markov chains, and stochastic kernels-, enable to highlight the overall evolution and relative performance of each region, as well as the nature of its mobility within the productivity distribution (up- or downward).

The rest of the paper is organized as follows. Section 2 surveys the main theoretical an empirical approaches on the convergence among the agricultural productivity levels in the European regions. Section 3 displays the methodology deployed. After that, some data issues are presented in Section 4 with a cluster analysis based on the structural characteristics of the regional agricultures. Section 5 shows the results and, finally, in Section 6 the main conclusions are presented.

2. Theoretical and empirical background

The relation between integration process and economic convergence has attracted much attention in theoretical and empirical literature. According to neoclassical models, growth in a context of liberalization and free competition leads to convergence across the different involved territories and productive sectors. Economies with a low initial level of productivity should grow more than economies with the highest levels. Under the assumptions of decreasing returns of capital, free factor mobility, free trade and technological diffusion, regional productivity levels would approach one another in the long term.

If the set of economies were very similar in terms of their economic structures (population growth rate, rate of saving, depreciation rate, rate of growth of technology), they would converge towards the same stationary state, and this would cause productivity disparities to diminish. In this case, convergence would be *absolute*. If, on the contrary, the economies were not identical, their stationary states would differ, and the differences in productivity would not necessarily diminish. This concept is known as *conditional* convergence (Barro and Sala-i- Martín, 1991).

Since the works of Romer (1986, 1990), Lucas (1988) and Grossman and Helpman (1991), a growing body of literature, known as endogenous growth models, has casted doubt on the optimistic predictions of the traditional neoclassical model laid out by Solow (1956). Together with physical capital, these models take into account the role of other factors such as technological, human and public capital, which generate externalities in the growth process. These sources of growth foster a virtuous circle of productivity improvement that drives a cumulative and sustained growth due to the non-diminishing returns.

In the case of the agricultural sector, the structural characteristics in terms of dimension, the agro-climatic conditions, the quality of the labour force, the specialization pattern, the agglomeration economies, the proximity to the market or the presence of dynamics externalities related to the interdependence with the rest of productive sectors, are some of the determining which may alter the convergence process because of the different impact on the regional productivity. Therefore, the stationary state of productivity is expected to vary across agricultures.

The degree of intervention must also be taken into account. Intervention and regulation measures articulated through the CAP interfere in the convergence process. Its measures and instruments have a different effect in each regional agricultural model and may distort the free market operation and the convergence path.

All these factors question the existence of an absolute convergence process in the European agricultural sector. Instead of convergence, the plurality of agriculture regional models configure a sector where the agricultures with weak structures (small economic and territorial dimension, aged and part-time labour, specialisation in productions less supported by the CAP) tend to remain in the low levels of the productivity ranking. Meanwhile, the most efficient agricultures consolidate their position in the head of the ranking.

Many researchers on regional imbalances in productivity have empirically tested the convergence theory using various methodologies. A considerable part of empirical literature is made up of cross-sectional and panel data regression analyses that focus on the behaviour of a representative economy (see Paci (1997), Paci and Pigliaru (1998), Colino and Noguera (1999, 2000), Colino *et al* (1999), Gil Canaleta (2001), and Castillo and Cuerva (2005) for the European agricultural sector). However, concentrating on the behaviour of a representative economy can only inform about the transition of this economy towards its own productivity stationary state without giving any information on the dynamics of the entire cross-sectional distribution (Quah, 1993; Quah, 1996a and 1996c).

The literature on the dynamics of the European regional productivity distribution is very scarce. Analyses carried out by Ezcurra *et al* (2007, 2008a, 2008b) are among the most important ones. The authors study a large sample of EU regions during the eighties and nineties. Through the calculation of density functions and stochastic kernels they find little mobility within the agricultural productivity distribution. This fact confirms the persistence of the disparities among agricultures at regional level and the difficulties to eliminate them in the future. The level of regional development and the sector investment mainly explain the disparities in the agricultural productivity levels.

Sassi (2006) confirms the high persistence in the agricultural productivity dynamics which is associated with a non competitive agricultural pattern and with high

CAP support dependence. The author highlights the advisability of a R&D policy that leads to innovation and farm growth to converge and to be more competitive, instead of increasing CAP support.

The analysis carried out in this paper pursues to test convergence under the hypothesis that the structural factors are inherent at each agriculture and very difficult to remove. This fact hinders productivity convergence and contributes to the persistence of disparities.

3. Methodology

This paper contributes to the existing empirical literature on convergence by adopting a methodological alternative to both cross-sectional and panel data regressions, in the spirit of the approach suggested by Quah (1993, 1996a, 1996b, 1996c, 1996d). This methodology directly examines the cross-sectional distribution of labour agricultural productivity, studying its intra-distributional dynamics and the changes in its external shape.

Density functions

The most common technique to analyse the evolution of the productivity distribution shape consists in the estimation and observation of the density function. This function shows the probability distribution of the productivity values in each period. The comparison across the different functions over time gives information about the changes in the external shape and the evolution of the disparities in productivity. If probability tends to concentrate around a value, convergence will take place towards this value. On contrary, if probability is dispersed, divergence will be the final outcome.

The main advantage of the density functions is that they serve to detect both mono- and multimodal behaviours. The presence of diverse modes informs about the existence of convergence clubs. Traditional measures of dispersion could not detect this aspect. Two distributions with the same level of dispersion may have a very different modal structure.

The estimation of the density function for productivity, *y*, in a certain point, *x*, is defined as follows:

$$\hat{f}(y^t) = \frac{1}{Nh}\sum_{i=1}^{n} K\left(\frac{x - y_i}{h}\right) \qquad (1)$$

where N is the number of regions; h is the bandwidth (or the smoothing parameter) which is equivalent to the length of the "bars" in the histogram and controls for the smoothness of the shape of the density function; and K is a kernel function that complies with:

$$\int_{-\infty}^{+\infty} K(t)dt = 1 \tag{2}$$

A kernel function is a weighting function that determines the shape of the bumps or peaks obtained when expression (1) is represented graphically. Since the efficiency of the different functions is always around 90%, the choice may be based on other aspects such as a straightforward calculation (Tortosa Ausina *et al*, 2005). We have used the Gaussian kernel in our estimates:

$$K(t) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}t^2} \tag{3}$$

The choice of the kernel function is not more important than the choice of the bandwidth, h (Silverman, 1986; Tortosa-Ausina *et al*, 2005). If h is too small, the graphic representation of the density function would generate an excessive number of peaks. This would cause a too erratic data structure. On the contrary, in the case of multiple modes, if h is too large this information may be hidden. Therefore, the number of modes is a decreasing function of h (Silverman, 1981). We use bandwidth h proposed by Silverman (1986) which provides reasonable results in a great number of situation and it is very easy to obtain (Goerlich, 2000). The expression is:

$$\hat{h} = 0{,}9An^{-1/5} \tag{4}$$

where A = minimum [standard deviation, (interquartilic range/1,394)].

Markov chain approach and stochastic kernels

However, the shape of the distribution may conceal important information (Epstein *et al*, 1999). The kernel densities do not reveal intra-distributional mobility along the regional productivity hierarchy. A region can move towards other side of the distribution, in such a way that a rich region could become poor and one poor region could become rich, without affecting the external shape of the distribution. Therefore, the rate of mobility does not depend on the distribution shape. Insignificant changes in the density functions may be not reflected graphically but they would be relevant to evaluate the convergence process in productivity.

In order to capture the transitional dynamics over time, Markov transition probability matrices are calculated (Quah, 1996d). These matrices allow us to know the probability of a region with a certain level of productivity to move towards higher or lower positions from one period to another. The set of data could be divided into several intervals of values which reflect the different positions that the observations could present. Each interval corresponds with a state. We define E = (e_0, e_1, e_2,…,e_n) as the set of achievable possible states of the variable in the case of *n* intervals. In each period, regions could remain in the same state of productivity or move towards another. The transition probability to e_j conditioned to be initially in e_i between *t+1* and *t* is defined as:

$$\Pr\,(X_{t+1}= e_j / X_t = e_i) = m_{ij} \qquad , \forall\, e_i, e_j \in E \qquad (5)$$

The set of m_{ij} is a *nxn* transition probability matrix, M, whose elements are not negative. In addition, the sum of each line of the matrix is equal to one. The diagonal elements represent the probability of regions to remain in the initial state. They give an idea of the degree of distribution mobility.

By assuming that the transition mechanism is time-invariant, the dynamics are described by an autoregressive process:

$$\varphi_{t+s} = (M \times M \times \ldots \times M)\, \varphi_t = M^s\, \varphi_t \qquad , \forall s \geq 1 \qquad (6)$$

where φ_t is a *1xn* probability distribution vector that summarizes the distribution in period *t*, and φ_{t+s} in period *t+ s*. Matrix M^s describes how the cross-sectional distribution evolves over time.

From the information provided by the transition probability matrix, we can characterize the hypothetical long-term distribution. There is a probability vector $\pi = [\pi_1, \pi_2, \ldots \pi_n]$, that implies:

$$\lim_{s\to\infty} M^s = \begin{pmatrix} \pi_1 & \pi_2 & & \pi_n \\ \pi_1 & \pi_2 & & \pi_n \\ & & & \cdot \\ \pi_1 & \pi_2 & & \pi_n \end{pmatrix} \tag{7}$$

The probability of finding the process in a certain state, for instance *j*, after a large number of transitions tends to π_j, and is independent of the initial probability distribution. Vector π is the stationary state or the equilibrium distribution of the Markov chain. It describes the long-run limit of the distribution of income (productivity) across economies (Durlauf and Quah, 1998). This limit is known as ergodic distribution. If the probability mass is mainly concentrated around the central state of productivity, this indicates that there is a process of convergence towards the mean. Alternatively, if the probability is distributed among different states, the distribution is polarized and the convergence hypothesis must be rejected.

However, this strategy entails a disadvantage. Results are sensitive to the way in which the number and the length of the states are defined. This choice is subjective by the researchers and affects the final results. To avoid this problem Quah (1996a, 1997a) and Durlauf and Quah (1998) suggest replacing the transition probability matrix with other instrument which reflects the transition probabilities among a hypothetical number of infinite states. The result is a continuous version of the transition matrix known as stochastic kernel. Its formal derivation may be consulted in the abovementioned works.

A stochastic kernel is a three-dimensional plot which reflects the density function of the productivity distribution (Z-axis) over the period *t+s* (X-axis), conditioned on the values corresponding to the previous period *t* (Y-axis). In other words, the kernel values are obtained by estimating the joint density functions in *t* and *t+s* and then dividing it by the implicit marginal distribution in order to calculate the conditional probabilities. Unfortunately, they do not provide information on the ergodic distribution.

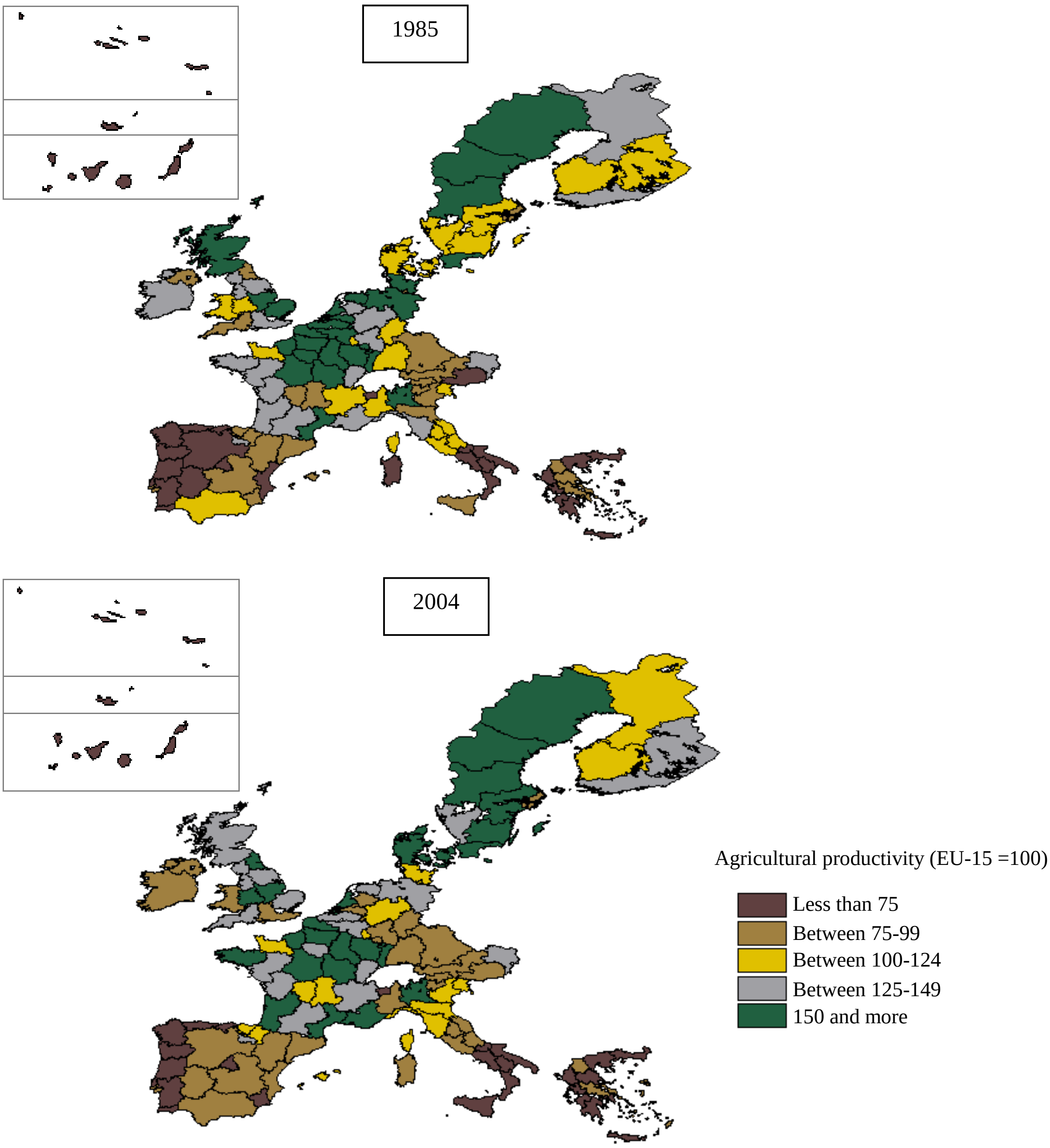
4. Data issues: a cluster analysis

The analysis has required data on agriculture productivity for 125 EU-15 regions, measured as the real GVA per worker at basic prices. These data are provided by *Cambridge Econometrics European regional database* for the period 1985-2004. Being designed to cover all EU regions, this database makes comparative analyses possible. Additionally, it completes the lacking information in Eurostat regional database for several sector- and regional-level variables, such as production, employment or investment. *Cambridge Econometrics database* enables researchers to get time- and space-specific information for the whole period of time and regions selected, under the same methodology of ESA-95 (European System of Accounts).

When it comes to selecting the territorial unit, it is important that the largest regions are not overvalued in the deployed data-set. This could happen if we only use information at NUTS2 level. In this sense, we have used a combination of the different NUTS levels. The detailed list may be found in the Appendix A.

Figure 1 shows the regional agricultural productivity relative to the EU-15 mean in 1985 and 2004. Two conclusions can be drawn from this figure. Firstly, there are considerable differences across regions. In 1985, the productivity in Madeira was only 13% of the EU-15 average, while in Mellersta Noorland it was 271%. In 2004, this picture has marginally changed. Secondly, disparities were still evident in 2004.

Figure 1. Agricultural productivity relative to the EU-15 average, 1985 and 2004



Source: *Cambridge Econometrics*

A great part of these disparities in productivity are due to the different socio-structural characteristics of agricultures. In order to classify regions according to their agriculture sector structure we have carried out a factor analysis based on several specific characteristics of the holdings, following Colino *et al* (1999). For the year 2000 we have considered variables referring to the territorial and economic dimension, labour force characteristics and specialization pattern (see Table 1). Data are provided by the

Farm Structure Survey (Eurostat). The analysis is not performed jointly for all the variables because of the potential problems in the interpretation of results (Colino *et al*, 1999). Therefore, we have considered each group of variables separately.

Table 1. Variables used in factor analysis

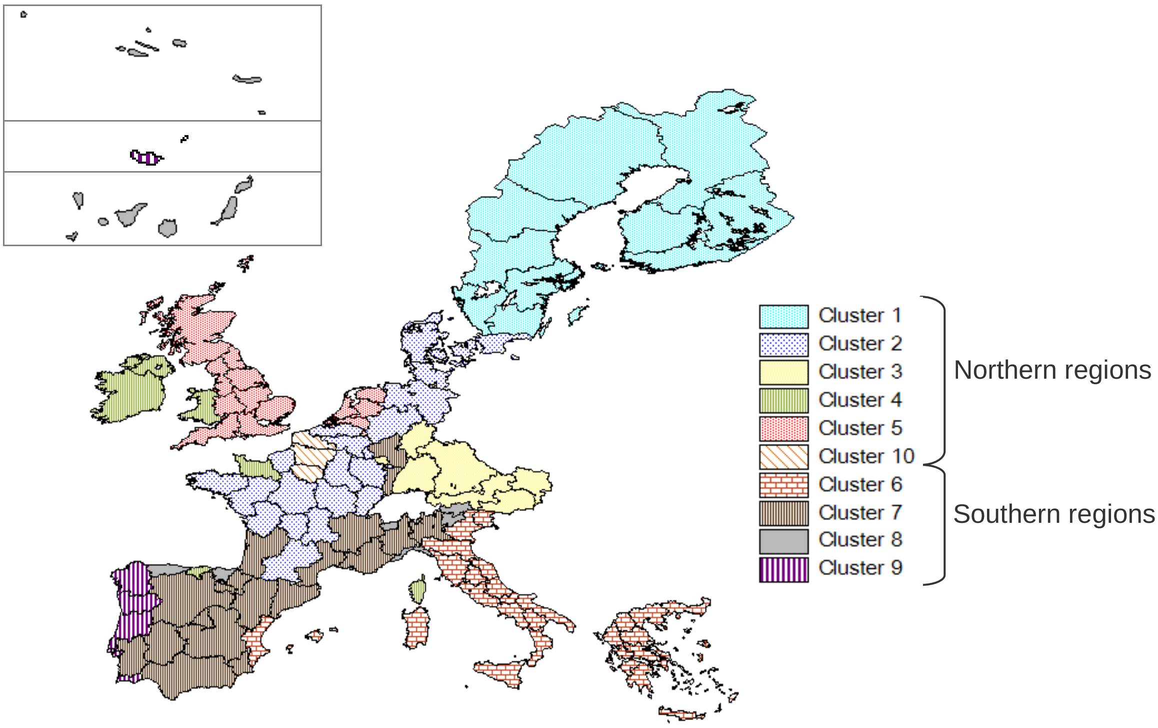
Kind of variable	Name	Definition[1]
Territorial dimension	Agricultural surface	AA/ Total holdings
	% of small holdings	Holdings with less than 5 ha AA/ Total holdings
	% of big holdings	Holdings with more than 50 ha AA/ Total holdings
	% of surface occupied by small surface holdings	AA of holdings with less than 5 ha AA /Total AA
	% of surface occupied by big surface holdings	AA of Holdings with more than 50 ha AA /Total AA
Economic dimension	Value of production	SGM/ Total holdings.
	% of small economic dimension holdings	Holdings with less than 2 ESU/ Total holdings
	% of big economic dimension holdings	Holdings with more than 100 ESU / Total holdings
	% of surface occupied by small economic dimension holdings	AA of Holdings with less than 2 ESU /Total holdings
	% of surface occupied by big economic dimension holdings	AA of Holdings with more than 100 ESU /Total holdings
Labour force characteristics	Family labour force	Family labour force in AWU/Total AWU
	Full-time family labour force	Full-time family labour force in AWU/ Total AWU
	Share of young labour force	Holder labour force < 35 years in AWU/ Total holder AWU
	Share of elder labour force	Holder labour force > 55 years in AWU/ Total holder AWU
	Partial dedication	Holder labour force with work time < 50% in AWU / Total holder AWU
	Full dedication	Holder labour force with work time = 100% in AWU/ Total holder AWU
Productive especialization	Cereal especialitation	Holdings with cereals / Total holdings
	Vegetable especialitation	Holdings with vegetables/ Total holdings
	Permanent crop especialization	Holdings with permanent crops/ Total holdings
	Vineyard especialization	Holdings with vineyard/ Total holdings
	Forage plant especializtion	Holdings with forage plants/ Total holdings
	Root crop especialization	Holdings with root crops/ Total holdings
	Pasture and meadow especialization	Holdings with pasture and meadows/ Total holdings
	Livestock especializattion	Holdings with livestock/ Total holdings

Source: Own elaboration

[1] AA: Agricultural Area (in ha)
SGM: Standard Gross Margin
ESU: European Size Unit (1 ESU = 1.200 € of SGM)
AWU: Annual Work Unit

The results of the factor analysis have been used to perform a cluster analysis based on Euclidian distance and intergroup linkage[2]. Figure 2 shows the resulting classification and Table 2 summarises the main characteristics of the ten clusters.

Figure 2. Cluster typology



Source: *Farm Structure Survey* (Eurostat).

The less efficient agricultures are grouped in clusters 6, 7, 8 and 9. They represent the European Southern agricultures and include, mainly, all the regions of Portugal, Greece and Italy and most of Spain. Compared to the Northern regions, they generally face smaller economic and territorial dimension, more degree of ageing of the labour force, more family labour force meaning less salaried labour force and less full-time dedication to the agricultural tasks. These characteristics contribute to explain the lower levels of productivity in Southern European agricultures. We compute the Standard Gross Margin per agricultural area as a proxy of the labour productivity. The main differences in productivity between Northern and Southern regions are due to the low levels of mechanization (AA/AWU) in the Southern agricultures (Table 2).

[2] Because of space reasons, it has been impossible to include a more detailed description of the analysis performed. A more detailed description may be obtained from the author upon request.

Table 2. Main socio-structural characteristics by cluster of agricultures

Cluster	AA/Holding (ha)	SGM/Holding (ESU)	% family AWU	% Holder AWU over 55 years old	% Holder AWU with time work = 100%	SGM/AWU (ESU/AWU)	SGM/AA (ESU/ha)	AA/AWU (ha/AWU)
Cluster 1	31.51	23.46	82.00	30.42	63.18	21.67	0.74	29.11
Cluster 2	43.35	48.10	61.17	28.51	74.97	36.29	1.11	32.71
Cluster 3	19.51	18.57	88.12	24.44	63.83	18.22	0.95	19.14
Cluster 4	33.73	21.89	86.44	40.80	72.90	18.43	0.65	28.41
Cluster 5	55.69	68.02	62.82	46.58	71.75	38.51	1.22	31.53
Cluster 10	66.67	74.50	45.26	25.24	79.25	43.06	1.12	38.54
Northern regions	*37.47*	*38.67*	*71.03*	*32.63*	*70.77*	*30.09*	*1.03*	*29.15*
Cluster 6	5.17	7.22	83.51	54.51	31.56	11.67	1.40	8.36
Cluster 7	24.01	19.36	61.35	40.25	55.89	20.39	0.81	25.30
Cluster 8	7.80	8.78	80.61	46.35	51.20	8.53	1.13	7.57
Cluster 9	4.86	5.23	87.80	62.88	40.64	4.11	1.08	3.82
Southern regions	*10.63*	*10.37*	*76.50*	*51.42*	*40.87*	*13.14*	*0.98*	*13.47*
EU-15	**18.73**	**18.68**	**73.40**	**44.47**	**51.90**	**19.91**	**1.00**	**19.96**

Source: *Farm Structure Survey* (Eurostat).

Differences are also observed in terms of specialization. In broad terms, Northern regions are specialised in continental productions (mainly cereal crop) and Mediterranean productions are more important (vegetables, vineyard) in the South.

Therefore, the existence of an array of structural patterns of agricultures is confirmed. This diversity conditions productivity and efficiency outcome. For this reason, defending a single model of European agriculture does not seem to be the best option for policy makers.

5. Results

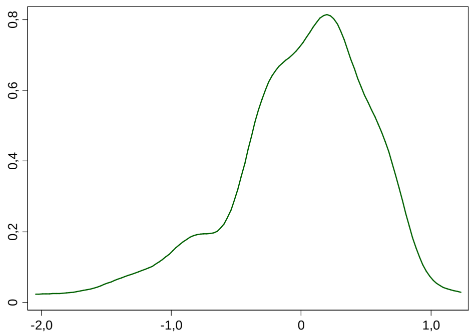
Figure 3 shows the results of the estimation of the density functions for five years: 1985, 1990, 1995, 2000 and 2004. Productivity is expressed in logs and is divided by the sample mean. In the X-axis the variable takes value 0 if the level of productivity is equal to the European mean; a value of 1 indicates the double of the mean; a value of -1 indicates the half and so forth. The possible outlier effect is mitigated with this transformation, which is especially important in the use of non-parametric techniques (De Jorge y Suárez, 2008).

The density functions identify one mode over time. However, there are changes in the shape since 1985. In the initial year, the distribution is concentrated around the values slightly above the European mean. Until 2000, the distribution moves closer to these values. From this year on, the probability mass is concentrated around the mean values due to the loss of weight of the values above the mean. Therefore, the mode has moved from values above the mean to values just below the European mean.

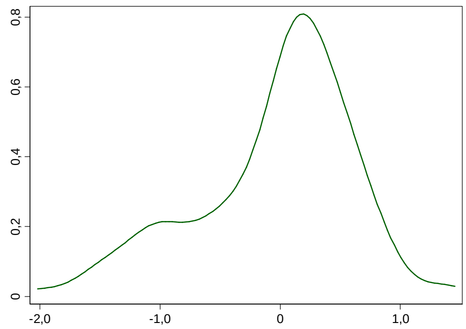
In 2004 a second group of regions appear in the lower extreme of the productivity distribution. These territories correspond to the Portuguese regions of Centro, Madeira, Norte and Azores. As this polarization arises at the end of the period, we can not draw any conclusions out of it. Nevertheless, bimodality seems to emerge, confirming a stratification process.

Figure 3. Density functions of the agricultural productivity relative to the EU mean, 1985-2004

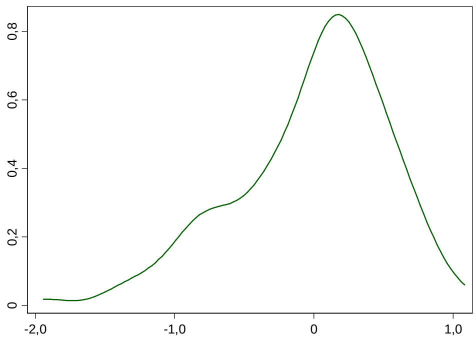
1985 (h = 0.1565)



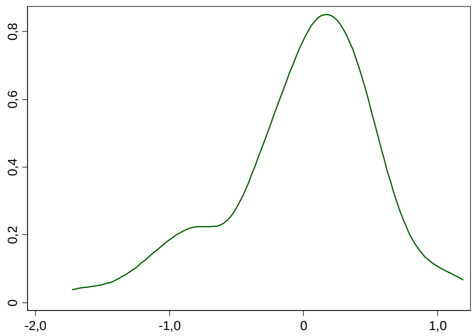
1990 (h = 0.1782)



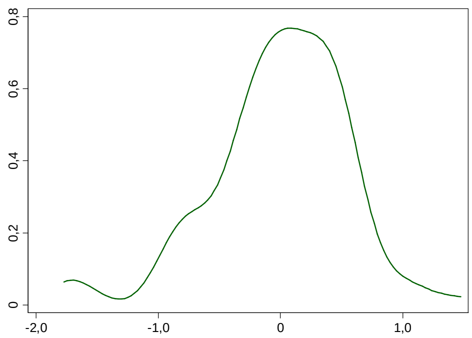
1995 (h = 0.1763)



2000 (h = 0.1647)



2004 (h = 0.1681)

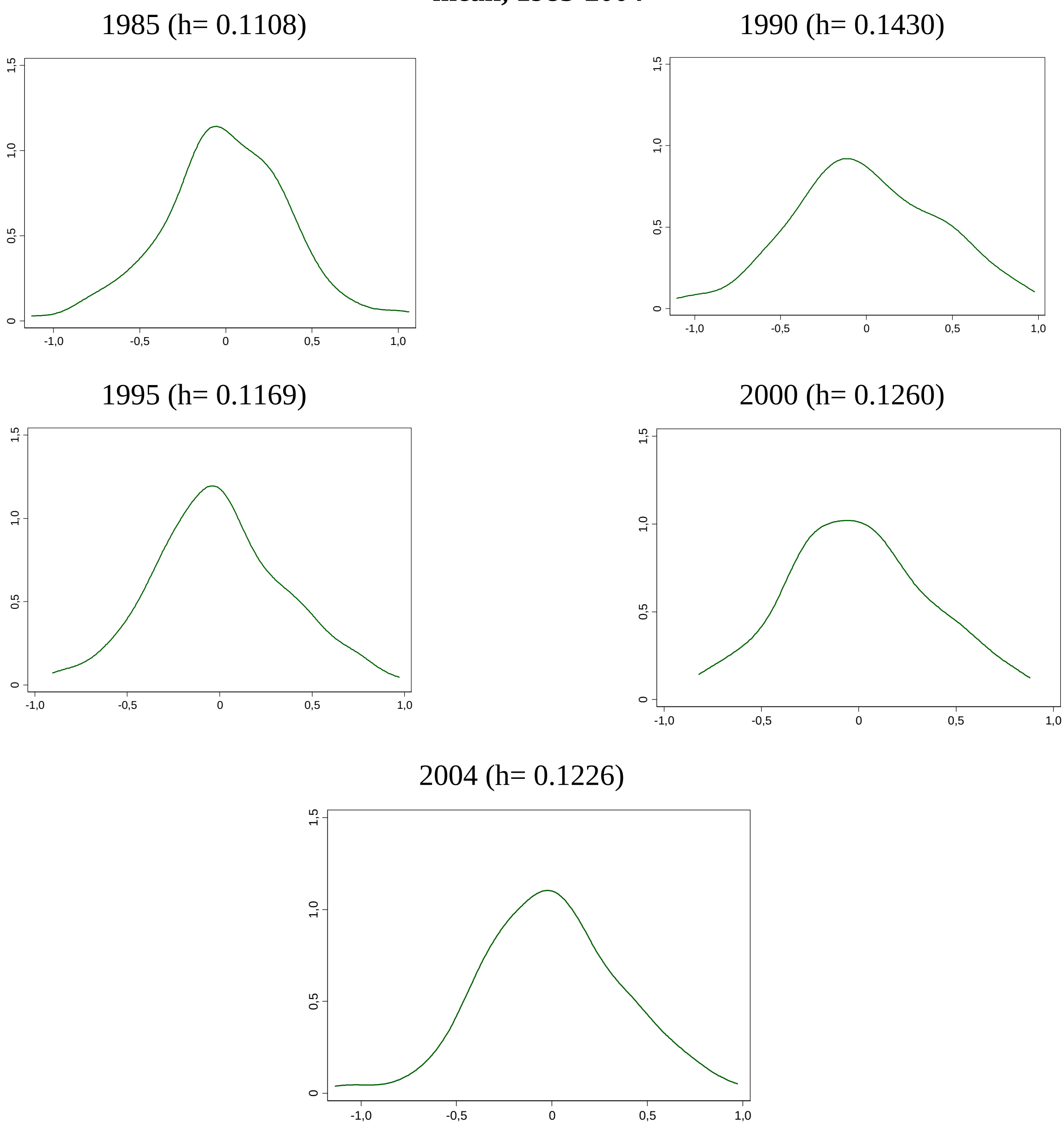


Source: *Cambridge Econometrics.*

Density functions allow us to observe how a set of factors or characteristics may alter the productivity distribution (Quah, 1997a). It is possible that regional agricultures converge towards the mean value of the corresponding cluster instead of approaching the European mean.

A new productivity series has been constructed as in Quah (1996b, 1997a, 1997b). We divide regional productivity by the mean value of the cluster. Figure 4 shows the density functions which reflect the importance of the socio-structural patterns in the explanation of the productivity dynamics. If the clusters had no sense and agricultural productivity were not affected by the structural characteristics of the regional holding, the shape of the conditioned distribution would not be altered with respect to the original one.

Figure 4. Density functions of the agricultural productivity relative to the cluster mean, 1985-2004



Source*: Cambridge Econometrics.*

The distribution of the new series is more concentrated around the mean and has a lower level of dispersion than the previous one. There are not incipient modes, as in the original distribution. As time goes by, the distribution becomes similar to a normal and symmetric one, with an only mode around the mean. Therefore, the structural characteristics play an important role in the productivity dynamics and condition the convergence process.

However, the analysis carried out does not take into account that regions could modify their relative positions within the distribution. To address this problem and complete the previous results we estimate the transition probability matrix. We compute quintiles for the productivity distribution in the initial year in order to achieve a good balance between the number of regions in each state of the matrix and the sensibility to changes in the relative positions. According to their level of productivity, regions are in one of the five mutually exclusive states. The categories or states correspond to low, low-medium, medium, medium-high and high productivity, in relation to the European mean.

A decision needs to be made about the time gap between the transitions from one state to another. It does not need to be one year long. After all, one year could be not enough time to detect changes or to appreciate convergence or divergence trends. That is why we will consider annual (from t to $t+1$) and five-year transitions (from t to $t+5$).

Table 3 illustrates the results on the annual transition matrix. The first row and column represent the interval or state of productivity. The first state refers to regions with levels of productivity below 70% of the EU mean; the second one includes regions between 70% and 93%, and so forth.

The main diagonal of the transition matrix displays regions which have remained in the same state throughout the analysed period. A high degree of persistence is found, particularly in both extremes of the distribution. 93% of low-productivity regions have remained in the initial state. Only the remaining 7% have moved to higher levels. Nearly 90% of high-productivity agricultures remain in their initial relative position. The highest mobility is registered in the medium-high state: 32% of regions in this state have moved to a different one.

The ergodic distribution displays relevant information: in the long term, the distribution has a unimodal shape. The highest probability is concentrated in the state close to the EU average (24.85%), as the nearest states lose significance. However, the probability of remaining in the low-productivity state increases with respect to 1985. There is a slow convergence towards the medium levels of the distribution and certain degree of polarization in the lowest productivity state is also observed.

Table 3. Annual probability transition matrix, 1985-2004

	[0-70)	[70-93)	[93-123)	[123-152)	[152-∞)
[0-70)	93.08	6.54	0.37	0.00	0.00
[70-93)	10.37	70.32	19.02	0.29	0.00
[93-123)	0.17	11.09	74.23	14.16	0.34
[123-152)	0.24	0.48	19.29	67.62	12.38
[152-∞)	0.00	0.00	1.03	10.06	88.91
Ergodic distrib.	23.00	14.61	24.85	17.26	20.12
2004 distrib.	20.80	19.20	22.40	17.60	20.00

Source: *Cambridge Econometrics*

Table 4 overviews the five-year probability transition matrix. This matrix displays the probability of moving from one state to another after five years. Compared to the analysis above, the matrix presents lower levels of persistence. There are more transitions among states every five years than every year. Most of low-medium productivity regions (84%) remain in the same state at the end of the period. Persistence is still high in the extremes of the distribution, but there is more dynamism than before. More than 25% of low-medium productivity agricultures have moved up, while nearly 35% of medium-high productivity regions have moved down. The ergodic distribution presents a higher concentration in the middle compared to the initial year. The probability of being in the lowest state of productivity also increases. This indicates that a slight convergence process towards the mean levels has taken place.

Table 4. Five-year probability transition matrix, 1985-2004

	[0-70)	[70-93)	[93-123)	[123-152)	[152-∞)
[0-70)	84.82	13.39	1.79	0.00	0.00
[70-93)	21.33	52.00	24.00	2.67	0.00
[93-123)	1.71	13.68	58.12	19.66	6.84
[123-152)	0.00	2.22	32.22	51.11	14.44
[152-∞)	0.00	1.89	2.83	15.09	80.19
Ergodic distrib.	23.86	15.06	23.94	16.78	20.49
2004 distrib.	20.80	19.20	22.40	17.60	20.00

Source: *Cambridge Econometrics*

The agricultural productivity distribution is characterised by low mobility throughout the observation period. This fact is in line with the large strand of the literature which shows how common persistence in the European regional transitions is (López-Bazo *et al*, 1999; Magrini, 1999; Mora, 2008). Persistence is especially high in the low and high levels of productivity, in such a way that movements are concentrated in the medium states. Convergence in 1985-2004 is mainly explained by regions close to average productivity, rather than improvements of low-productivity regions.

In this context, it could be useful to condition the distribution. If, after conditioning the distribution, the transition matrix does not show any movement (in other words, the matrix is similar to an identity matrix), that will mean that the conditioning variables do not explain the dynamics of the distribution at all (Quah, 1996b).

Table 5 shows the annual transition matrix conditioned by the structural characteristics. As before, the distribution is normalised by the cluster mean and the quintiles in 1985 have been used to define the states. Persistence still prevails, but the mean probability displayed on the main diagonal is lower. Low relative productivity regions are more prone to move up in the distribution than before. Persistence in the highest state of productivity is nearly 90%. The ergodic distribution shows a higher probability of being in the extreme categories in the long term. Compared to the non-conditioned distribution, the probability of ending up in the highest state is higher (23.49%), regardless of the initial state. If there were not differences in the structural characteristics of the agricultures, convergence to higher states would be observed. Therefore, these differences are an obstacle for the convergence in the European agricultures.

Table 5. Annual transition matrix conditioned by the structural characteristics, 1985-2004

	[0-77)	[77-92)	[92-108.6)	[108.6-131)	[131-∞)
[0-77)	85.46	13.29	0.72	0.54	0.00
[77-92)	17.84	61.89	18.72	1.54	0.00
[92-108.6)	0.45	20.86	62.81	15.42	0.45
[108.6-131)	0.00	1.03	18.81	65.98	14.18
[131-∞)	0.00	0.00	0.56	9.53	89.91
Ergodic distrib.	23.36	18.60	18.31	16.10	23.49
2004 distrib.	21.60	17.60	20.80	17.60	22.40

Source: *Cambridge Econometrics*.

The five-year transition matrix is computed in Table 6. In this longer transition period mobility is higher in all the states. About 27% of low-productivity regions and 40% of low-medium productivity regions have moved towards higher level states. The extreme states accumulate most of the probability mass in the ergodic distribution, especially the highest productivity state.

Table 6. Five-year transition matrix conditioned by the structural characteristics, 1985-2004

	[0-77)	[77-92)	[92-108.6)	[108.6-131)	[131-∞)
[0-77)	72.73	18.18	6.61	2.48	0.00
[77-92)	25.27	37.36	28.57	8.79	0.00
[92-108.6)	9.00	26.00	45.00	15.00	5.00
[108.6-131)	2.70	8.11	22.97	48.65	17.57
[131-∞)	0.88	0.00	4.39	7.89	86.84
Ergodic distrib.	24.23	16.87	19.43	13.67	25.64
2004 distrib.	21.60	17.60	20.80	17.60	22.40

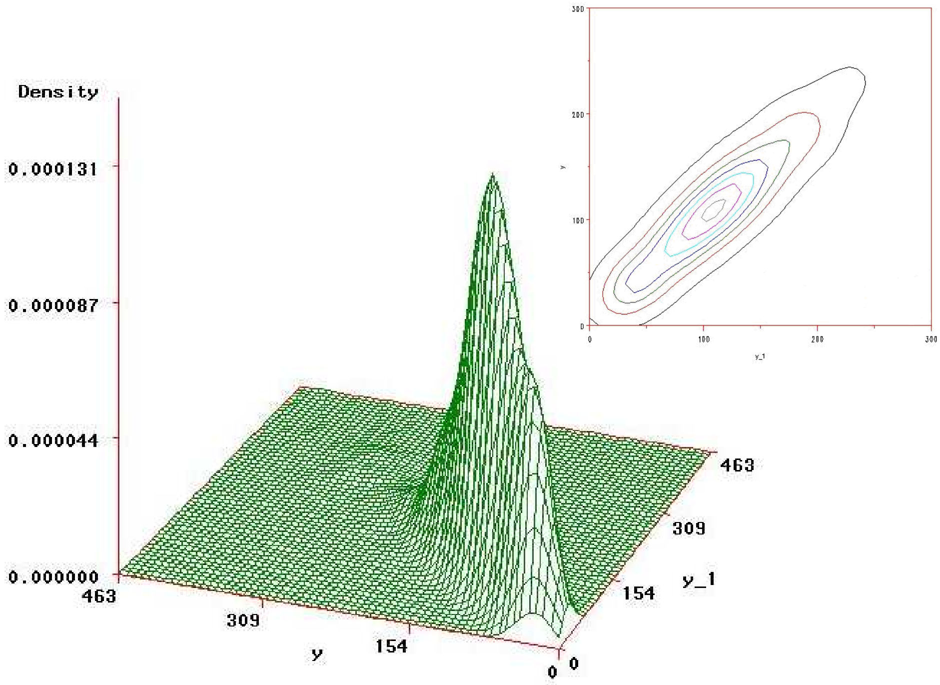
Source: *Cambridge Econometrics.*

To sum up, mobility within the probability distribution has been rather low. Economies tend to concentrate near the mean values as a result of changes within the distribution, but the extremes resist to change. The implications on convergence are not so positive. Convergence is slow and tends towards a relatively uniform distribution. Both less efficient agricultures and those with the highest levels of productivity keep their initial positions. Mobility increases when we condition by the structural patterns, as well as the probability to end up in the highest productivity state. Differences in the agricultural structures affect the distribution dynamics, hindering the transition towards higher levels of productivity.

In order to avoid subjectivity in the selection of the different states of relative productivity, we estimate the stochastic kernel. Figure 5 illustrates the results for annual transitions. If most of the probability mass is concentrated around the positive diagonal, the distribution will be characterised by high levels of persistence. This happens to be the case here. Therefore, it can be interpreted as evidence of low mobility, confirming the previous results. The European agricultures tend to maintain their relative positions. In addition, Figure 5 shows that the peak of the distribution is concentrated around values slightly above the European mean.

A contour plot is also included in Figure 5. Each line reflects a cut parallel to the X- and Y- axis for different density values. The lines connect, therefore, points with the same densities. We find that the probability mass is concentrated around the positive diagonal and the width of the contour lines is narrow. This confirms the small degree of mobility within the distribution. The European agricultures are unlikely to change their positions from one year to another.

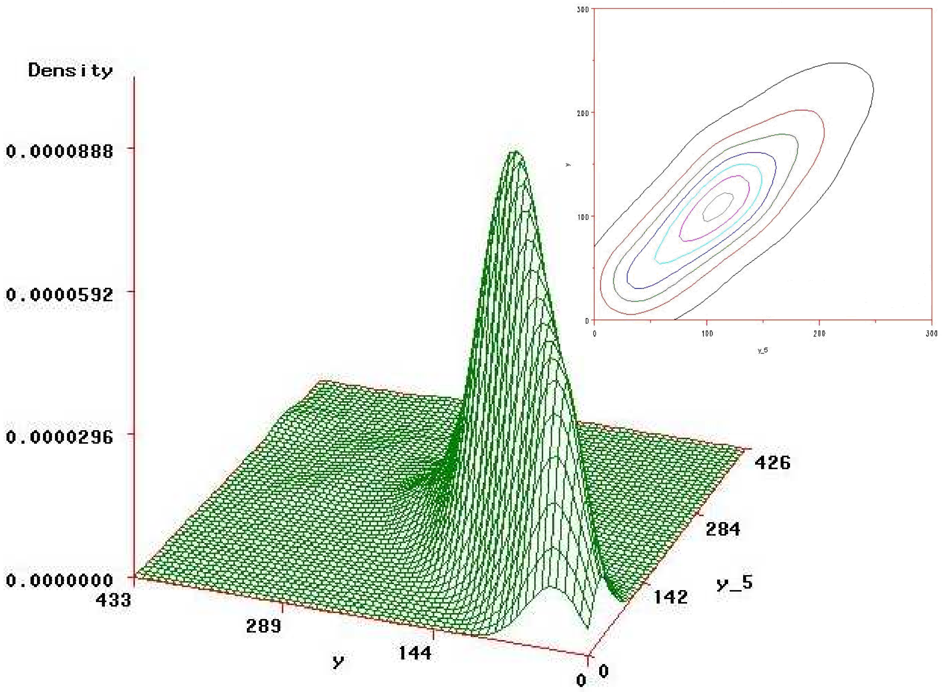
Figure 5. Stochastic kernel for annual transitions, t and t+1, 1985-2004



Source: Cambridge Econometrics.

Figure 6 presents the stochastic kernel for five-year transitions. Although persistence is still high, the contour lines are wider. When we expand the observation period of transitions, there are more frequent movements and higher mobility. The peak is also concentrated around the values slightly above the mean.

Figure 6. Stochastic kernel for five-year transitions, t and t+5, 1985-2004



Source: Cambridge Econometrics.

In line with Ezcurra *et al* (2008b), our results suggest low mobility within the agricultural productivity distribution. We confirm that regions generally maintain their relative positions in the period 1985-2004. Regions tend to end up where they started.

6. Conclusions

This paper analyses the evolution of the regional agricultural productivity based on the hypothesis of persistent differences due to the existence of different structural patterns. Productivity is measured as the real GVA at basic prices per worker for a set of 125 EU-15 regions in the period 1985-2004.

The paper contributes to the existing literature by developing a methodological alternative to both cross-sectional and data panel regressions. Density functions, Markov chains, and stochastic kernels are combined to highlight the overall evolution and relative performance of each region, as well as the nature of its mobility.

The results suggest no evidence of strong absolute productivity convergence across regions. It is true that the mode of the distribution is around the EU average but the probability mass concentrated around the highest and lowest levels of productivity is significant as well.

Given that regions tend to remain in their relative positions of productivity, regional productivity disparities across the EU are large and persistent. The higher mobility is observed in the medium-high productivity regions, while persistence is higher in the extremes of the distribution, particularly in the lowest extreme. This situation is unlikely to change in the future.

Our analysis reveals that there are ten different models of agricultures in terms of their structural patterns. Differences in the economic and territorial size, the labour force and the productive specialization are evident and condition the evolution of the productivity.

The distribution dynamics changes when we take into account these different agricultural models. Distribution is more concentrated around the mean values and the mobility within the distribution is higher. The main conclusion of the paper is that divergences in agricultural labour productivity across regions will continue if the current differences in the structural patterns persist in the future.

7. References

BARRO, R. y SALA-I-MARTÍN, X. (1991): "Convergence across states and regions", *Brookings Papers on Economic Activity*, vol. 22(1), pp. 107-182

CASTILLO, J.S. y CUERVA, M.C. (2005): "Análisis de la convergencia en productividad agraria en las regiones europeas", *Economía agraria y recursos naturales*, nº 10, pp. 89-106

COLINO, J. y NOGUERA, P. (1999): "La difícil convergencia de las agriculturas europeas, en España", en DELGADO, J.L. (dir.): *Economía: Ante el siglo XXI*, Espasa Forum, Madrid, pp. 111-127

COLINO, J. y NOGUERA, P. (2000): "Patrones estructurales y convergencia interregional en la agricultura europea", *Historia Agraria*, nº 22, pp. 111-128

COLINO, J., NOGUERA, P. y RODRÍGUEZ, M. (1999): *La agricultura gallega en la Unión Europea: Balance del primer decenio*, Fundación La Caixa Galicia

DE JORGE, J. y SUÁREZ, C. (2008): "Evaluación de la eficiencia y la productividad de las empresas de distribución minorista en el período 1996-2002", *ICE*, nº 841, pp. 181-192

DURLAUF, S.N. y QUAH, D. (1998): "The new empirics of economic growth", *CEP Discussion Paper*, nº 384, Center for Economic Performance, London School of Economics

EPSTEIN, P., HOWLETT, P. y SCHULZE, M.X. (1999): "Income distribution and convergence: the European experience, 1870-1992", *Economic History Working Papers*, nº 52/99, Department of Economic History, London School of Economics and Political Science

EZCURRA, R., IRAIZOZ, B., PASCUAL, P. y RAPÚN, M. (2007): Agricultural Productivity in the European Regions: Trends and Explanatory Factors, Documentos de Trabajo FUNCAS, nº 309

EZCURRA, R., IRAIZOZ, B., PASCUAL, P. y RAPÚN, M. (2008a): "Tendencias y factores explicativos de la productividad agraria en las regiones europeas", *Papeles de Economía Española*, nº 117, pp. 44-58

EZCURRA, R., IRAIZOZ, B., PASCUAL, P. y RAPÚN, M. (2008b): "Spatial disparities in European agriculture: a regional análisis", *Applied Economics*, vol. 40(13), pp. 1669-1684

GALOR, O. (1996): "Convergence? Inferences from Theoretical Models", Economic Journal, Royal Economic Society, vol. 106(437), pp. 1056-1069

GIL CANALETA, C. (2001): *Capital público y convergencia en las regiones europeas*, Civitas, primera edición, Madrid

GOERLICH, F.J. (2000): *Desigualdad, diversidad y convergencia: Mas instrumentos de medida – Estadística descriptiva-*, primera edición, IVIE

GROSSMAN, G.M. y HELPMAN, E. (1991): *Innovation and growth in the global economy*, MIT Press, Cambridge

LÓPEZ-BAZO, E., VAYÁ, E., MORA, A.J. y SURIÑACH, J. (1999): "Regional economic dynamics and convergence in the European Union", *The Annals of Regional Science*, vol. 33(3), pp. 343-370

LUCAS, R. (1988): "On the mechanics of economic development", *Journal of Monetary Economics*, vol. 22(1), pp. 3-42

MAGRINI, S. (1999): "The evolution of income disparities among the regions of the European Union", *Regional Science and Urban Economics*, vol. 29(2), pp. 257-281

MORA, A.J. (2008): "Factors conditioning the formation of European regional convergence clubs", *The Annals of Regional Science*, vol. 42(4), pp. 911-927

PACI R. (1997): "More similar and less equal. Economic growth in the European regions", *Weltwirtschaftliches Archiv*, vol. 133(4), pp. 609-634

PACI, R. y PIGLIARU, F. (1998): "European regional growth: Do sectors matter?", en ADMAS, J. y PIGLIARU, F. (eds): *Economic growth and change. National and Regional Patterns*, Edward Elgar, Cheltenham, pp. 213-235

QUAH, D. (1993): "Empirical cross-section dynamics in economic growth", *European Economic Review*, vol. 37(2-3), pp. 426-434

QUAH, D. (1996a): "Empirics for economic growth and convergence", *European Economic Review*, vol. 40(6), pp. 1353-1375

QUAH, D. (1996b): "Regional convergence clusters across Europe", *European Economic Review*, vol. 40(3-5), pp. 951-958

QUAH, D. (1996c): "Convergence empirics across economies with (some) capital mobility", *Journal of Economic Growth*, vol. 1(1), pp. 95-124

QUAH, D. (1996d): "Convergence as distribution dynamics (with or without growth)", *CEP Discussion Paper*, nº 317, Center for Economic Performance, London School of Economics and Political Science

QUAH, D. (1997a): "Empirics for growth and distribution: stratification, polarization and convergence clubs", *Journal of Economic Growth*, vol. 2(1), pp. 27-59

QUAH, D. (1997b): "Regional cohesion from local isolated actions: II. Conditioning", *CEP Discussion Paper*, nº 379, Centre for Economic Performance, London School of Economics and Political Science

ROMER, P. (1986): "Increasing returns and long run growth", *The Journal of Political Economy*, vol. 94(5), pp. 1002-1037

ROMER, P. (1990): "Endogenous Technological Change", *Journal of Political Economy*, vol. 98(5), pp. 71-102

SASSI, M. (2006): “Agricultural convergence and competitiveness in the EU-15 regions”, Comunicación presentada en la *Conferencia de la Asociación Internacional de Economía Agraria*, Gold Coast, Australia

SILVERMAN, B. (1986): *Density estimation for statistics and data analysis,* Chapman & Hall, London

SOLOW, R. (1956): “A contribution to the theory of economic growth”, *Quarterly Journal of Economics,* vol. 70(1), pp. 65-94

TORTOSA-AUSINA, E., PÉREZ, F., MAS, M. y GOERLICH, F.J. (2005): “Growth and convergence profiles in the Spanish provinces (1965–1997)”, *Journal of Regional Science,* vol. 45(1), pp. 147-182

Appendix A. Selected regions

BELGIUM (NUTS 2)
BE2 Vlaams Gewest
BE3 Region Walonne

DENMARK (NUTS 2)
DK Denmark

GERMANY (NUTS 1)
DE1 Baden-Wurttemberg
DE2 Bayern
DE5 Bremen
DE6 Hamburg
DE7 Hessen
DE9 Niedersachsen
DEA Nordrhein-Westfalen
DEB Rheinland-Pfalz
DEC Saarland
DEF Schleswig-Holstein

GREEK (NUTS 2)
GR11 Anatoliki Makedonia
GR12 Kentriki Makedonia
GR13 Dytiki Makedonia
GR14 Thessalia
GR21 Ipeiros
GR22 Ionia Nisia
GR23 Dytiki Ellada
GR24 Sterea Ellada
GR25 Peloponnisos
GR3 Attiki
GR41 Voreio Aigaio
GR42 Notio Aigaio
GR43 Kriti

SPAIN (NUTS 2)
ES11 Galicia
ES12 Asturias
ES13 Cantabria
ES21 País Vasco
ES22 Navarra
ES23 La Rioja
ES24 Aragón
ES3 Madrid
ES41 Castilla-León
ES42 Castilla-La Mancha
ES43 Extremadura
ES51 Cataluña
ES52 Com. Valenciana
ES53 Baleares
ES61 Andalucía
ES62 Murcia
ES7 Canarias

FRANCE (NUTS 2)
FR1 Ile de France
FR21 Champagne-Ard.
FR22 Picardie
FR23 Haute-Normandie
FR24 Centre
FR25 Basse-Normandie
FR26 Bourgogne
FR3 Nord-Pas de Calais
FR41 Lorraine
FR42 Alsace
FR43 Franche-Comte
FR51 Pays de la Loire
FR52 Bretagne
FR53 Poitou-Charentes
FR61 Aquitaine
FR62 Midi-Pyrenees
FR63 Limousin
FR71 Rhone-Alpes
FR72 Auvergne
FR81 Languedoc-Rouss.
FR82 Prov-Alpes-Cote d'Azur
FR83 Corse

IRELAND (NUTS 1)
IE Ireland

ITALY (NUTS 2)
ITC1 Piemonte
ITC2 Valle d'Aosta
ITC3 Liguria
ITC4 Lombardia
ITD1-2 Trentino-Alto Adige
ITD3 Veneto
ITD4 Fr.-Venezia Giulia
ITD5 Emilia-Romagna
ITE1 Toscana
ITE2 Umbria
ITE3 Marche
ITE4 Lazio
ITF1 Abruzzo
ITF2 Molise
ITF3 Campania
ITF4 Puglia
ITF5 Basilicata
ITF6 Calabria
ITG1 Sicilia
ITG2 Sardegna

LUXEMBOURG (NUTS 2)
LU Luxembourg

NETHERLAND (NUTS 1)
NL1 Noord-Nederland
NL2 Oost-Nederland
NL3 West-Nederland
NL4 Zuid-Nederland

AUSTRIA (NUTS 1)
AT1 Ostosterreich
AT2 Sudosterreich
AT3 Westosterreich

PORTUGAL (NUTS 2)
PT11 Norte
PT16 Centro
PT17 Lisboa
PT18 Alentejo
PT15 Algarve
PT2 Acores
PT3 Madeira

FINLAND (NUTS 2)
FI13 Itä-Suomi
FI18 Etelä-Suomi
FI19 Länsi-Suomi
FI1A Pohjois-Suomi
FI2 Åland

SWEDEN (NUTS 2)
SE01 Stockholm
SE02 Ostra Mellansverige
SE04 Sydsverige
SE06 Norra Mellansverige
SE07 Mellersta Norrland
SE08 Ovre Norrland
SE09 Smaland med oarna
SE0A Vastsverige

U. KINGDOM (NUTS 1)
UKC North East
UKD North West
UKE Yorkshire and the Humber
UKF East Midlands
UKG West Midlands
UKH Eastern (East of England)
UKJ South East
UKK South West
UKL Wales
UKM Scotland
UKN Northern Ireland