# Dynamics of European agricultural productivity: An analysis of regional convergence

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***Summary*** *– This paper analyses the evolution of the European agricultural productivity distribution under the hypothesis of persistent differences in productivity levels over time. We use the Cambridge Econometrics European Regional Database and work on a sample of 125 EU-15 regions from 1985 to 2004. Density functions, transition matrices and stochastic kernels are combined to study the dynamics of the productivity distribution. We observe no evidence of strong productivity convergence. Regional disparities across European agricultures are large and persistent. The highest levels of persistence are concentrated in both extremes of the productivity distribution. Additionally, we propose a regional typology on the basis of different structural patterns according to the economic and territorial dimension of the holdings, the characteristics of the labour force and the productive specialization. The main result is that the diversity of patterns conditions productivity and hinders sectoral convergence. Divergence in agricultural productivity will continue if differences in structural patterns persist in the future.*

***Keywords:*** *agricultural productivity, European regions, convergence, density function, Markov chains, stochastic kernels*

## Dynamique de la productivité agricole européenne : une analyse de convergence régionale

**Résumé** – L'objectif de cet article est d'analyser l'évolution de la distribution de la productivité agricole européenne sous l'hypothèse de la persistance des différences entre les niveaux de productivité sur le long terme. Nos données proviennent de la base de données du *Cambridge Econometrics*. Nous avons travaillé sur un échantilon de 125 régions de l'UE-15, de 1985 à 2004. Nous avons combiné les fonctions de densité, les matrices de transition et l'analyse stochastique pour étudier la dynamique de la distribution de la productivité. Les résultats indiquent qu'il n'existe pas de processus de convergence rapide. Les disparités entre les agricultures européennes sont importantes et persistantes. La plus grande persistance est observée aux deux extrémités de la distribution. De plus, nous présentons une typologie régionale basée sur différents modèles structurels : la dimension économique et territoriale des exploitations, les caractéristiques de la main-d'œuvre et la spécialisation productive. Les résultats mettent en évidence que la diversité de modèles conditionne la productivité et complique la convergence sectorielle. La divergence de la productivité agricole européenne se poursuivra si les différences de modèles structurels persistent dans l'avenir.

**Mots-clés :** productivité agricole, régions européennes, convergence, fonction de densité, matrices de transition, analyse stochastique

**JEL Classification**: R11, Q10

# 1. Introduction

The diversity of productive structures explains part of the economic regional disparities. In this sense, the European Union (EU) agricultural sector is one of the most heterogeneous. This lack of homogeneity implies huge productivity and income differences among European agricultures. The reduction of these disparities within the sector has been an important objective for economic policy makers since the beginning of the European integration process.

From the perspective of the neoclassical theory of economic integration, the reinforcement of the European Common Market should imply convergence in productivity and efficiency levels of the different productive sectors. In the particular case of agriculture, the existence of the Common Agricultural Policy (hereinafter CAP), with the same guidelines for all member States, should stimulate convergence. Nevertheless, even nearly fifty years after the introduction of the CAP, convergence is not assured. Natural conditions, climate, geographical situation, specialization patterns, dimension of the holdings, proximity to consumption centres, innovative capacity or endowment of productive factors (land, labour, physical and human capital), highlight the existence of important disparities in the European agricultural sector. These factors condition the possibilities of endogenous development in such a way that the convergence mechanisms activated with the integration process are counteracted.

Interest in regional economic convergence has increased since the nineties. Many studies have tried to provide evidence for the EU convergence process in terms of regional GDP per capita or per worker, but a conclusive answer is not yet available. In addition, in most studies, sector considerations are not taken into account.

This paper aims to analyse the evolution of regional agricultural productivity in order to find out whether convergence takes place. In the agricultural sector, productivity levels are clearly related to cyclical influence but also to socio-structural characteristics (size of the holdings, characteristics of the labour force, productive specialization). Therefore, this research contributes to the convergence literature by introducing the different structural patterns in the European agricultures as a conditioning factor of regional productivity.

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. Most studies use the REGIO database from Eurostat, which is affected by the lack of continuity in the data series. For that reason, employment and production data used to calculate productivity are drawn from the Cambridge Econometrics European Regional Database.

Normally, studies have tested convergence from the traditional methodology of $\beta$ and $\sigma$ convergence. These approaches do not report interesting information related to the dynamics of the whole productivity distribution. Therefore, with the aim of analysing convergence from the point of view of the evolution of the productivity dispersion and the mobility within the distribution, we follow Quah's (1993, 1996a and 1996c) non-parametric approaches: density function, Markov chains and stochastic kernels. These tools 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). Our analysis is in line with the convergence analyses carried out for the EU agricultural sector by Ezcurra *et al.* (2008 and 2011). The main difference is that the aforementioned works pay attention to specific characteristics of the region or sector (country to which a region belongs, investment *per* worker, regional *per capita* income, characteristics of the owner of the holding) that could explain the differences in agricultural productivity, including them one by one in the analysis. In this paper, we are conscious of the importance of the structural characteristics of regional agricultures. But these characteristics cannot be taken into account separately because all of them together shape different patterns of agricultures. For that reason, we consider more appropriate to carry out a cluster analysis taking into account 24 variables related to four dimensions of the agricultural holdings (territorial area, economic size, labour force and productive specialization) which help to define different structural patterns in the sector.

The rest of the paper is organized as follows. Section 2 surveys the main theoretical and empirical approaches on convergence of agricultural productivity levels in the European regions. After that, some data issues are presented in section 3 with a cluster analysis based on the structural characteristics of the regional agricultures. Section 4 shows the results and, finally, in section 5, 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 in recent years, regarding the intensification and the enlargement of the European integration process. Since the appearance of the endogenous growth models and the neoclassical "contra-revolution" in the nineties, the empirical analyses have focused on the dichotomy convergence *vs.* divergence.

According to neoclassical models, in a context of liberalization and free competition growth leads to convergence in relative productivity levels across the different involved territories and productive sectors. Economies with an initial low productivity level should grow more than those ones 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. This convergence process speeds up with the intensification of the integration markets (López-Bazo *et al.*, 1999).

If economies were very similar in terms of their economic structures (population growth rate, rate of saving, depreciation rate, technology growth rate), they would converge towards the same stationary state, and this would cause productivity disparities to diminish in the long term. 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).

Other studies adopt a different approach, highlighting the endogenous factors of regional growth. Since Romer (1986 and 1990), Lucas (1988), and Grossman and

Helpman (1991), a growing body of literature has casted doubt on the optimistic predictions of the traditional neoclassical model. Together with physical capital, the endogenous growth models take into account the role of other factors such as technological, human and public capital, which generate a virtuous circle of productivity improvements leading to cumulative and sustained growth due to the non-diminishing returns. The market forces tend to concentrate the production and, therefore, disparities increase.

One of the limitations of the neoclassical and endogenous growth models is that they only consider the direct sources of economic growth, without paying attention to other regional-specific factors, which produce either convergence or divergence in productivity.

In the EU agricultural sector, the structural characteristics in terms of the dimension of the holdings, the characteristics of the labour force, the degree of mechanization or the productive specialization influence productivity and condition the convergence process to different stationary states. The plurality of regional agricultures according to these structural factors forms a sector where the agricultures with weak structures (small economic and territorial dimension, aged and part-time labour, low degree of mechanization, specialization in productions less supported by the CAP) tend to remain in the lowest positions of the productivity ranking. Meanwhile, the most efficient agricultures consolidate their position in the head of the ranking.

Many researchers on regional imbalances 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 (for European agricultural sector, see Paci, 1997; Paci and Pigliaru, 1998; Rezitis, 2010; Colino *et al.*, 1999; Colino and Noguera, 2000; Castillo and Cuerva, 2005; Alexiadis and Alexandrakis, 2008; Sassi, 2010). However, these studies only inform about the transition of this representative economy towards its own productivity stationary state without giving any information on the dynamics of the entire cross-sectional distribution (Quah, 1993, 1996a and 1996c).

The literature on the dynamics of the EU agricultural productivity distribution is still very scarce. Analyses carried out by Ezcurra *et al.* (2008 and 2011) are the only ones for which we have evidence. 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 low mobility within the agricultural productivity distribution. The differences in the levels of regional development, in the country to which the region belongs, and in the sector investment, mainly explain the disparities in agricultural productivity. Nevertheless, some characteristics of the agricultural holdings and owners make minor significant contribution to the explanation of disparities in the sector.

This paper uses different tools to obtain more information about the dynamics of agricultural productivity distribution at EU regional level in order to test convergence. The initial hypothesis is that differences in agricultural structural patterns hinder convergence and contribute to the persistence of disparities in productivity.

## 3. Data issues: a cluster analysis

The analysis has required data for 125 EU-15 regions on: *i)* labour agriculture productivity, measured as the real GVA *per* worker at constant prices, and *ii)* structural characteristics of holdings.

Production and employment data are provided by the 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 overcomes the lack of information in Eurostat regional databases for several sector- and regional-level variables, such as production, employment or investment, resorting to official national statistics. Cambridge Econometrics Database enables to get time- and space-specific information for the whole period of time and regions selected, under ESA-95 (European System of Accounts) methodology.

The information about the structural characteristics of holdings is collected from the Farm Structure Survey (Eurostat). This survey provides data about the size and the kind of holding, the use of land, the farm diversification activities (livestock and agriculture products), the labour force (including age and full- or part- time dedication) and other aspects related to the agricultural management practices.

When it comes to selecting the territorial unit, it is important that the largest regions are not overvalued in the deployed dataset. This could happen if we only use information at NUTS2 level. To avoid this problem, we have used a combination of the different NUTS levels. The selected sample includes 125 territorial units: Belgium (2), Denmark (1), Germany (10), Greece (13), Spain (17), France (22), Ireland (1), Italy (20), Luxembourg (1), Netherlands (4), Austria (3), Portugal (7), Finland (5), Sweden (8) and the United Kingdom (11). The detailed list may be found in appendix A [1].

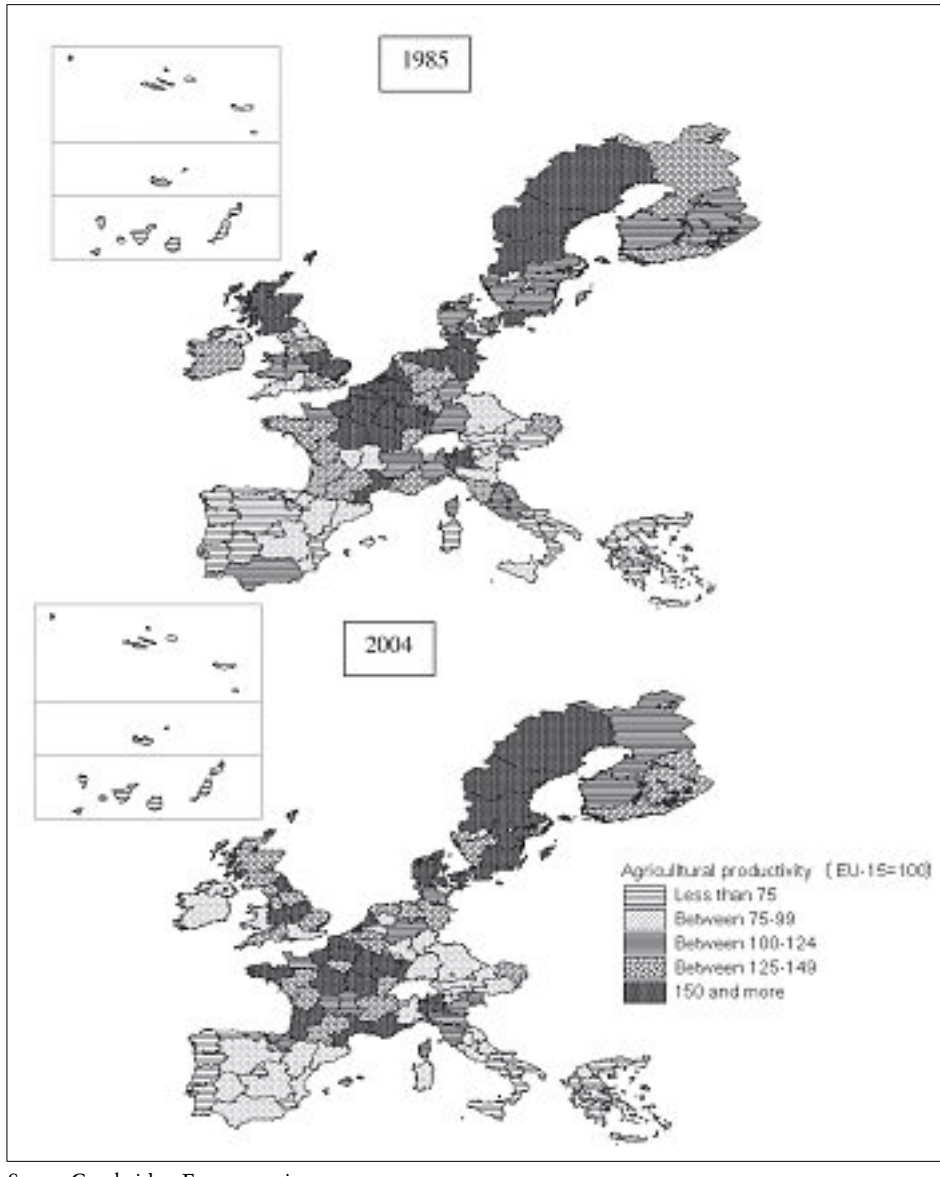
Figure 1 shows the regional agricultural productivity relative to the EU-15 mean in 1985 and 2004. There are considerable differences across regions. In 1985, the productivity in Madeira (Portugal) was only 13% of the EU-15 average, while in Mellersta Noorland (Sweden) it was 271% of the mean. By 2004, this picture had marginally changed and disparities were still evident.

To what extent may the structural characteristics and the productive specialization condition the unequal evolution of the productivity? With the purpose of dealing with this question, we use multivariate statistical techniques. Following Colino *et al.* (1999), our aim is to provide a typology of the selected regional agricultures by examining their sector structure based on several specific characteristics of the holdings.

From the 2000 Farm Structure Survey we have combined for each region variables related to four dimensions: territory, economic size, labour force and productive

[1] Some regions have been eliminated from the sample: regions of Eastern Germany (Berlin, Brandemburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt and Thuringen) due to the lack of data for the whole period; Brussels and London because of their insignificant levels of agricultural production and employment which could distort the results; and the overseas territories of France as well as the Spanish territories of Ceuta and Melilla because of their small size and peripheral location.

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




*Source:* Cambridge Econometrics

specialization [2]. Different ratios have been calculated. They give important information to characterize regional agricultures on the basis of their structure (see table 1).

[2] Data for German regions of Bremen and Hamburg are presented together. For this reason, the number of observations is reduced to 124. In addition, data for the Italian region of Trentino-Alto Adagio have been obtained by adding the data for the provinces of Trento and Bolzano.

Table 1. **Variables used to characterize the regional agricultures**

| Kind of variable | Name | Definition [(a)] |
|---|---|---|
| **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 |
| | Family labour force full-time employed | Full-time family labour force/ Family labour force (person) |
| | Share of young labour force | Holder age < 35 years in AWU/ Total holders AWU |
| | Share of elder labour force | Holder age > 55 years in AWU/ Total holders AWU |
| | Part-time dedication | Holder labour force with work time < 50% in AWU/ Total holders AWU |
| | Full-time dedication | Holder labour force with work time = 100% in AWU/ Total holders AWU |
| **Productive specialization** | Cereal specialization | Holdings with cereals/Total holdings |
| | Vegetable specialization | Holdings with vegetables/Total holdings |
| | Permanent crop specialization | Holdings with permanent crops/ Total holdings |
| | Vineyard specialization | Holdings with vineyard/Total holdings |
| | Forage plant specialization | Holdings with forage plants/ Total holdings |
| | Root crop specialization | Holdings with root crops/Total holdings |
| | Pasture and meadow specialization | Holdings with pasture and meadows/ Total holdings |
| | Livestock specialization | Holdings with livestock/Total holdings |

*Notes:* [(a)]: AA: Agricultural Area (in ha); SGM: Standard Gross Margin (in Euros); ESU: European Size Unit (1 ESU = 1.200 € of SGM); AWU: Annual Work Unit
*Source:* Own elaboration

One potential problem consists in the interpretation of the resulting typology with these 24 variables. For this reason, a factor analysis has been carried out to summarize the information provided by the ratios. The analysis is not performed

jointly for all variables. Instead, each group of variables has been considered separately. From the Principal Component Analysis, seven factors have been found to reduce the information contained in the 24 original variables. The criterions for factor extraction have been the Kaiser-Meyer-Olkin coefficient, the Bartlett's test of sphericity and the determinant of the correlation matrix.

Table 2 presents the results for the factor analysis. All the factors obtained have eigenvalues greater than one and explain more than 70% of the variance of the original variables used in each analysis.

For the territorial dimension, one factor has been extracted, which distinguishes between large and small size of the holdings in each region.

For the economic dimension, the factor obtained separates agricultures with larger economic size class of farms from smaller ones.

Two factors have been obtained for the labour dimension. One of them measures the importance of part-time agriculture and the other one refers to the age of the holders.

Finally, three factors have been extracted for the productive dimension. The first one measures the specialization in livestock and pasture and meadows; the second one identifies agricultures specialized in cereal and forage plants and the last factor considers the variables which show the specialization in vegetables and root crops.

These factors have been used to perform a hierarchical clustering analysis. Euclidian distance has been chosen as the distance measure between two observations and intergroup-linkage is used as the clustering procedure. Figure 2 shows the resulting classification in ten groups and table 3 summarises the main characteristics of each cluster. After clustering, a discriminant analysis has been performed to confirm that more than 95% of regions have been correctly grouped. The results prove the suitability of the analysis carried out.

The less efficient agricultures are grouped in clusters 6, 7, 8 and 9. They represent the European Southern agricultures and include, mainly, all regions of Portugal, Greece and Italy and most Spanish regions. Compared to the Northern regions (clusters 1, 2, 3, 4, 5 and 10), the Southern agricultures generally present smaller economic and territorial dimension, higher degree of ageing of the labour force and more family labour force (that implies less salaried workers and less full-time dedication to agricultural tasks). These characteristics contribute to explain the lower levels of productivity in the Southern European agricultures. We compute the Standard Gross Margin (SGM) *per* agricultural area as a proxy of the labour productivity and break it down into SGM *per* ha (land productivity) and agricultural area *per* work unit (degree of mechanisation). The main differences in productivity between the Northern and the Southern regions are due to the low levels of mechanisation in the Southern agricultures, while the differences in land productivity are insignificant (table 3).

In terms of specialization, differences are also observed. The Northern regions are specialized in continental productions (mainly cereal crop) and Mediterranean productions (vegetables, vineyard) are more important in the South of Europe.

Table 2. **Summary of the factor analysis**

**Territorial dimension**

| Component | Eigenvalues | Explained variance (%) | Variables | Components |
|---|---|---|---|---|
| 1 | 3.930 | 78.590 | Agricultural surface | 0.903 |
| 2 | 0.610 | 12.206 | % of small holdings | – 0.869 |
| 3 | 0.293 | 5.861 | % of big holdings | 0.925 |
| 4 | 0.112 | 2.235 | % of surface occupied by small surface holdings | – 0.833 |
| 5 | 0.055 | 1.108 | % of surface occupied by big surface holdings | 0.900 |

Determinant of the correlation matrix = 0.004
KMO = 0.694
Barlett = 655.233 sig. 0.000

**Economic dimension**

| Component | Eigenvalues | Explained variance (%) | Variables | Components |
|---|---|---|---|---|
| 1 | 3.618 | 72.360 | Value of production | 0.971 |
| 2 | 0.760 | 15.201 | % of small economic dimension holdings | – 0.754 |
| 3 | 0.477 | 9.537 | % of big economic dimension holdings | 0.943 |
| 4 | 0.126 | 2.516 | % of surface occupied by small economic dimension holdings | – 0.689 |
| 5 | 0.019 | 0.386 | % of surface occupied by big economic dimension holdings | 0.861 |

Determinant of the correlation matrix = 0.003
KMO = 0.742
Barlett = 692.778 sig. 0.000

**Labour dimension**

| Component | Eigenvalues | Explained variance (%) | Variables | Comp. 1 | Comp. 2 |
|---|---|---|---|---|---|
| 1 | 3.659 | 60.976 | Family labour force | 0.591 | 0.098 |
| 2 | 1.215 | 20.253 | Family labour force full-time employed | – 0.930 | 0.200 |
| 3 | 0.814 | 13.572 | Share of young labour force | 0.026 | 0.971 |
| 4 | 0.177 | 2.951 | Share of elder labour force | 0.470 | – 0.829 |
| 5 | 0.096 | 1.595 | Part-time dedication | 0.842 | – 0.319 |
| 6 | 0.039 | 0.653 | Full-time dedication | – 0.886 | 0.403 |

Determinant of the correlation matrix = 0.002
KMO = 0.731
Barlett = 724.654 sig. 0.000

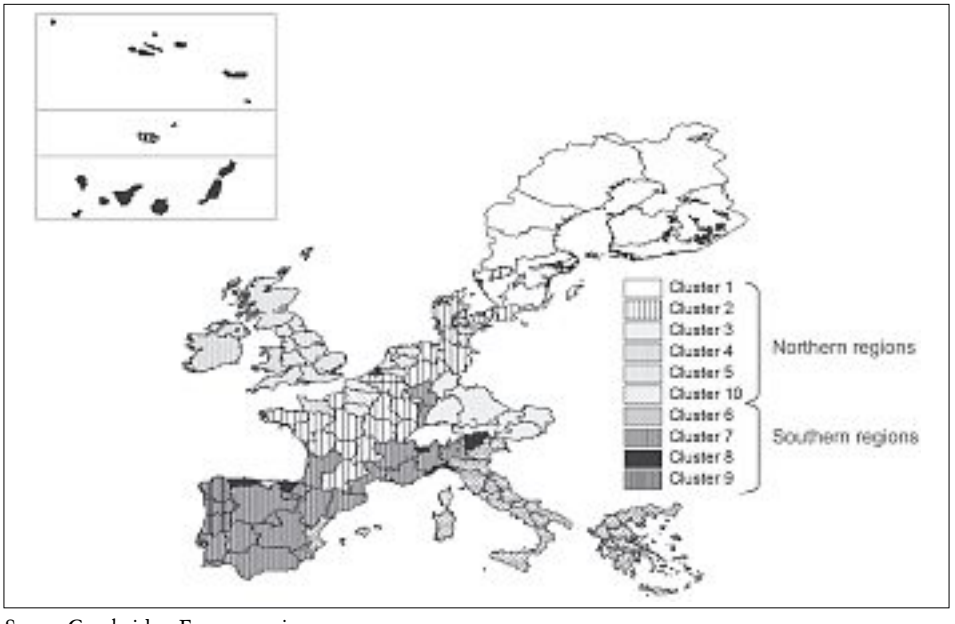
Table 2. **Summary of the factor analysis *(continued)***

| Productive dimension | | | | | | |
|---|---|---|---|---|---|---|
| Component | Eigenvalues | Explained variance (%) | Variables | Comp. 1 | Comp. 2 | Comp. 3 |
| 1 | 3.617 | 45.215 | Permanent crop specialization | – 0.766 | – 0.518 | 0.064 |
| 2 | 1.632 | 20.404 | Pasture and meadow specialization | 0.921 | – 0.066 | 0.005 |
| 3 | 1.056 | 13.204 | Forage plant specialization | 0.450 | 0.747 | – 0.060 |
| 4 | 0.672 | 8.394 | Rot crop specialization | 0.231 | 0.218 | 0.865 |
| 5 | 0.442 | 5.521 | Cereal specialization | 0.024 | 0.895 | 0.152 |
| 6 | 0.273 | 3.415 | Vineyard specialization | – 0.676 | – 0.306 | 0.188 |
| 7 | 0.215 | 2.686 | Vegetable specialization | – 0.240 | – 0.102 | 0.869 |
| 8 | 0.093 | 1.160 | Livestock specialization | 0.831 | 0.194 | 0.139 |

Determinant of the correlation matrix = 0.010
KMO = 0.638
Barlett = 549.331 sig. 0.000

*Note:* Factor analysis with principal component extraction and Varimax rotation
*Source:* Farm Structure Survey (Eurostat)

Figure 2. **Cluster typology based on structural patterns**




*Source:* Cambridge Econometrics

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

Table 3. **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)

# 4. Results

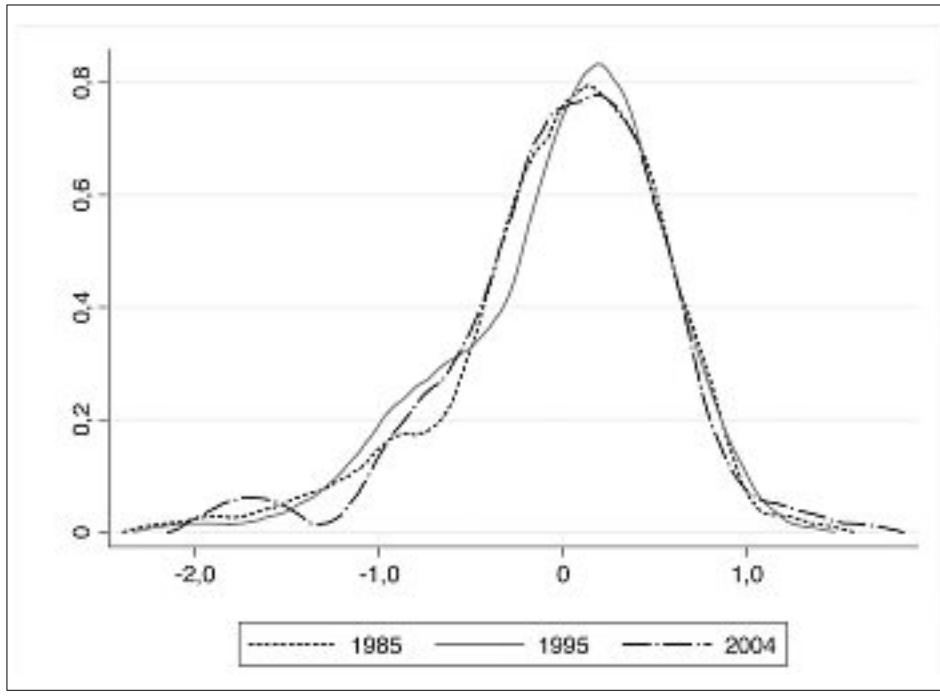
The paper contributes to the existing empirical literature on agricultural convergence by including the different typologies of agricultures and adopting an alternative methodology to both cross-sectional and panel data regressions, following Quah (1993, 1996a, 1996b, 1996c, 1996d). This methodology directly examines the distribution of the labour agricultural productivity through the study of its intra-distribution dynamics and the changes in its external shape. An excellent methodological survey by Magrini (2004) may be consulted.

In order to analyse the evolution of the productivity distribution shape-density functions are estimated. The main advantage of density functions is to detect mono- and multimodal behaviours. The presence of diverse modes informs about the existence of convergence clubs that could not be detected by traditional measures of dispersion.

Figure 3 plots the estimation of the density functions of the agricultural productivity for three years: 1985, 1995 and 2004. 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). As density estimator we use the Gaussian kernel. The plug-in method developed by Sheather and Jones (1991), which has some theoretical desirable properties that improve on the earlier procedures, is used as bandwich selector [3]. Productivity is expressed in logs and in relation to the

[3] For instance, see Jones *et al.* (1996) to know about the advantages of this bandwich selector.

Figure 3. **Density functions of the agricultural productivity relative to the EU-15 average (in logs), 1985, 1995 and 2004**



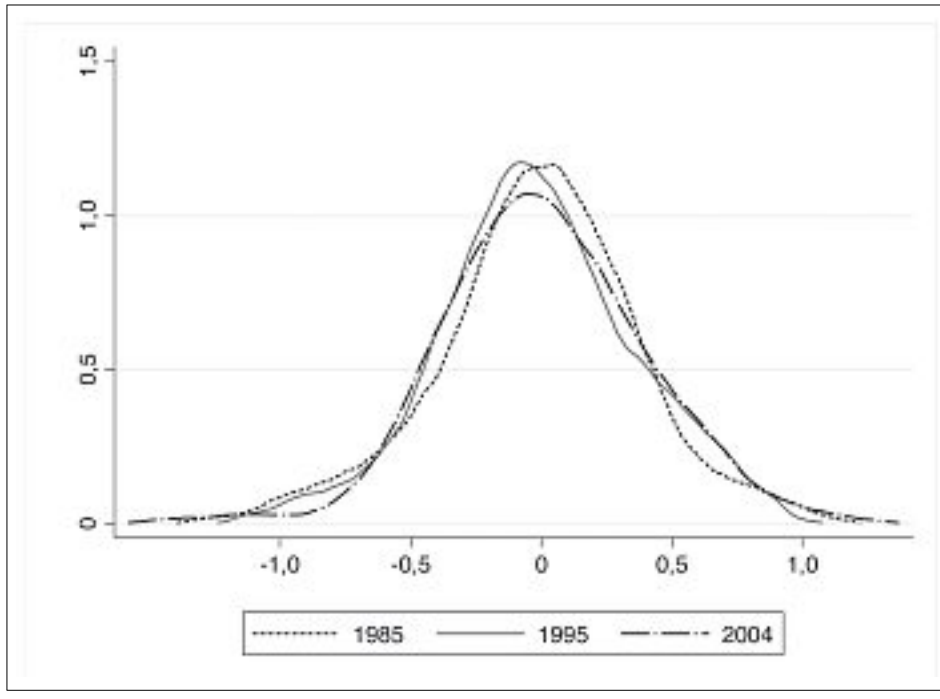

*Source:* Cambridge Econometrics

EU-15 average. The possible outlier effect is mitigated with this transformation, which is especially important in the use of non-parametric techniques. In the X-axis the variable takes value 0 if the level of productivity is equal to the EU-15 mean.

The external shape of the distribution shows small changes between 1985 and 2004. Similar to Ezcurra *et al.* (2008 and 2011), the density functions identify one mode over time. In the initial year, the distribution is concentrated around the values slightly above the EU mean. Until 1995, the concentration around these values increases but from this year on, it decreases for two reasons. One of them is the gain of weight of regions with productivity levels between 50% and 100% of the average. And the other reason is the loss of weight of regions with productivity values slightly above the average. Therefore, the mode has moved very slowly from values above the mean to values around it.

But one of the most interesting findings is the appearance of a second group of regions in the lowest extreme of the productivity distribution in 2004 (levels below 50% of the EU mean). These territories correspond to the Portuguese regions of Centro, Madeira, Norte and Azores. Bimodality seems to emerge in the last period, confirming a stratification process and a trend towards convergence to different productivity levels.

Figure 4. **Density functions of the agricultural productivity relative to the cluster average (in logs), 1985, 1995 and 2004**




*Source:* Cambridge Econometrics

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

A new productivity series has been constructed. Regional productivity has been divided by the mean value of the cluster. Figure 4 shows the importance of the socio-structural patterns in the explanation of the productivity dynamics. If the clusters had no sense and agricultural productivity was not affected by the structural characteristics of the holdings, the shape of the conditioned distribution would not be altered with respect to the original one.

More concentration around the mean and a lower level of dispersion are the main significant changes in the distribution of the new series during the period. There are not incipient modes, like in the original distribution. As time goes by, the distribution becomes similar to a normal, symmetric one, with a single mode around the mean. This reflects that convergence tends to occur within each cluster and it is consistent with the existence of multiple stationary states.

However, this analysis does not take into account that regions could modify their relative positions within the distribution. To address this problem and in order to

Table 4. **Five-year probability transition matrix of the agricultural productivity relative to the EU-15 average (in logs), 1985-2004**

| | > – 0.357 | [– 0.357, – 0.081) | [– 0.081, 0.201) | [0.201, 0.420) | < 0.420 |
|---|---|---|---|---|---|
| > – 0.357 | 83.72 | 14.19 | 2.09 | 0.00 | 0.00 |
| [– 0.357, – 0.081) | 17.06 | 50.79 | 29.37 | 2.78 | 0.00 |
| [– 0.081, 0.201) | 1.73 | 17.06 | 55.51 | 21.17 | 4.54 |
| [0.201, 0.420) | 0.85 | 2.54 | 29.58 | 45.35 | 21.69 |
| < 0.420 | 0.00 | 0.80 | 3.47 | 19.20 | 76.53 |
| Ergodic distrib. | 20.09 | 15.70 | 24.97 | 18.04 | 21.50 |
| 2004 distrib. | 20.80 | 19.20 | 22.40 | 17.60 | 20.00 |

*Source:* Cambridge Econometrics

capture the transitional dynamics over time, Markov transition probability matrices are calculated. These matrices allow computing the probability of a region with a certain level of productivity to move towards higher or lower positions in the distribution from one period to another. We compute quintiles for the productivity distribution relative to the EU mean (in logs) 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. Therefore, in 1985 each state includes 20% of the regions.

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

Table 4 illustrates the results on the transition matrix. The first row and column represent the interval or state of relative productivity in logs. Regions are in one of the five mutually exclusive states. If the logs are transformed the first state refers to regions with productivity levels below 70% of the EU mean; the second one includes regions between 70% and 93% of the mean, and so forth. Therefore, the states correspond to very low, low-medium, medium, medium-high and very high productivity in relation to the average across EU-15.

The main diagonal of the transition matrix displays the percentage of regions that have remained in the same state throughout the period of analysis. A high degree of persistence is found, particularly in both extremes of the distribution. In fact, more than 83% of low-productivity regions have remained in the initial state. Meanwhile, the probability that a region within this state moves right is only the remaining 16%. In the case of high-productivity agricultures, nearly 77% remain in their initial position. The highest mobility is registered in the medium-high state: about 55% of regions in this state have moved to a different one.

One of the main advantages of the transition probability matrix, $M$, is that it provides information about the hypothetical long-term distribution. There is a probability vector $\pi = [\pi_1, \pi_2, \ldots \pi_n]$, that implies:

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

The probability of finding the process in a certain state, for instance j, after a large number of transitions tends to $\pi_j$, and it is independent of the initial probability distribution. Vector $\pi$ is the stationary state or the equilibrium distribution of the transition matrix. It describes the long-run limit derived from the distribution of the productivity across regions (Durlauf and Quah, 1998). This limit is known as the 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, the distribution of probability among different states should be considered as polarization and the convergence hypothesis must be rejected.

The ergodic distribution displayed in table 4 shows relevant information: in the long term, the distribution has a unimodal shape. This conclusion is also reached in Ezcurra *et al.* (2008). The highest probability is concentrated in the state close to the EU average (24.97%), while the nearest states lose significance. There is a slow convergence towards the medium levels of the distribution mainly due to the behaviour of regions included in the states close to the EU average. A certain degree of polarization in the extreme state of productivity is also observed. This points out that the existing territorial imbalances in the European agriculture will persist into the future.

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

The five-year transition matrix conditioned by the cluster is computed in table 5. The distribution is normalised by the cluster mean and is expressed in logs. Quintiles in 1985 have been used to define the states. Persistence still prevails, but the mean probability displayed on the main diagonal is lower than in the non-conditioned matrix. About 30% and 35% of low and low-medium productivity regions have moved towards higher states, respectively. Low-productivity regions are more prone to move up in the distribution than before, although persistence in the lowest state of productivity is also high. Compared to the non-conditioned distribution, the probability of ending up in the highest state is higher (24.55%). The extreme states accumulate most of the probability mass in the ergodic distribution, especially the highest one. That result seems to confirm the idea that differences in the structural patterns are an obstacle for convergence in the European agricultures. If these differences were reduced, convergence towards higher states would be observed.

In spite of the information given by the transition matrices, this methodology entails a disadvantage. Results could be sensitive to the way in which the number and

Table 5. **Five-year transition matrix of the agricultural productivity relative to the cluster average (in logs), 1985-2004**

| | < – 0.259 | [– 0.259, – 0.079) | [– 0.079, 0.082) | [0.082, 0.273) | < 0.273 |
|---|---|---|---|---|---|
| < – 0.259 | 70.69 | 19.24 | 6.71 | 2.91 | 0.45 |
| [– 0.259, – 0.079) | 25.14 | 39.19 | 28.11 | 6.76 | 0.81 |
| [– 0.079, 0.082) | 8.16 | 27.11 | 39.36 | 22.74 | 2.62 |
| [0.082, 0.273) | 2.67 | 9.00 | 20.00 | 49.00 | 19.33 |
| < 0.273 | 0.96 | 1.20 | 3.86 | 9.88 | 84.10 |
| Ergodic distrib. | 22.88 | 18.16 | 17.94 | 16.47 | 24.55 |
| 2004 distrib. | 21.60 | 17.60 | 20.80 | 17.60 | 22.40 |

*Source:* Cambridge Econometrics

the length of the states are defined. This choice is subjective by the researchers and could affect the final results [4].

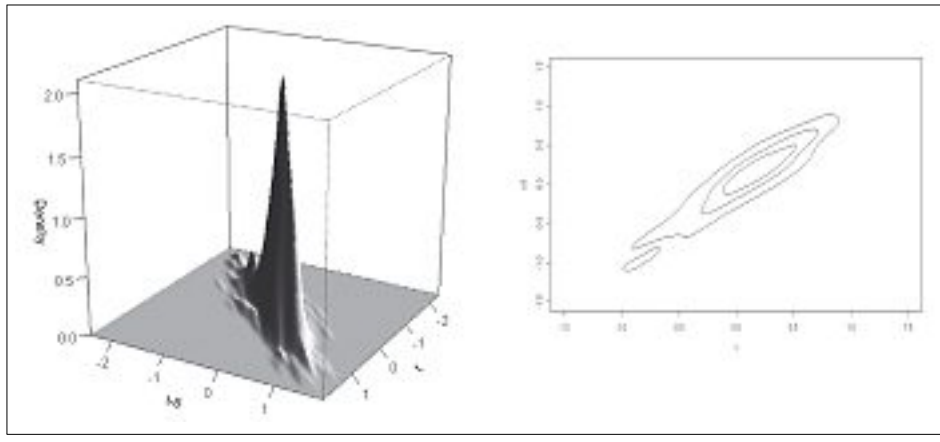
To test the robustness of the results of the transition matrices, Quah (1996a and 1997a), and Durlauf and Quah (1998) suggest replacing this matrix by other instrument, which reflects the transition probabilities among a hypothetical number of infinite states. The result is a continuous version of the transition matrix known as stochastic kernel. Its formal derivation may be consulted in the above mentioned works.

A stochastic kernel is a three-dimensional plot, which reflects the density function of the productivity distribution (Z-axis) over the period *t* (X-axis), conditioned on the values corresponding to the previous period *t-s* (Y-axis). In other words, the kernel values are obtained by estimating the joint density function in *t* and *t-s*, and then dividing it by the implicit marginal distribution in order to calculate the conditional probabilities.

Figure 5 illustrates the results for five-year 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. It can be interpreted as evidence of low mobility, confirming the previous results and those obtained by Ezcurra *et al.* (2011). The European agricultures tend to maintain their relative positions. In addition, figure 5 shows that the peak of the distribution is mainly concentrated around values slightly above the overall mean, but certain bimodality is observed. There is a second group of agricultures that start and end up with a relatively low level of productivity.

[4] We did different estimations varying the number of states (from 4 to 7 states) and the time gap between the transitions (from 2 to 5-year transitions). Obviously, the probabilities change, but the conclusions do not: the level of persistence is high, especially in the extremes of the productivity distribution. Therefore, we consider our results from the transition matrices robust, in spite of the subjectivity of this kind of methodology.

Figure 5. **Stochastic kernel of the agricultural productivity relative to the EU-15 average (in logs), (period *t* and *t*-5), 1985-2004**



*Source:* Cambridge Econometrics

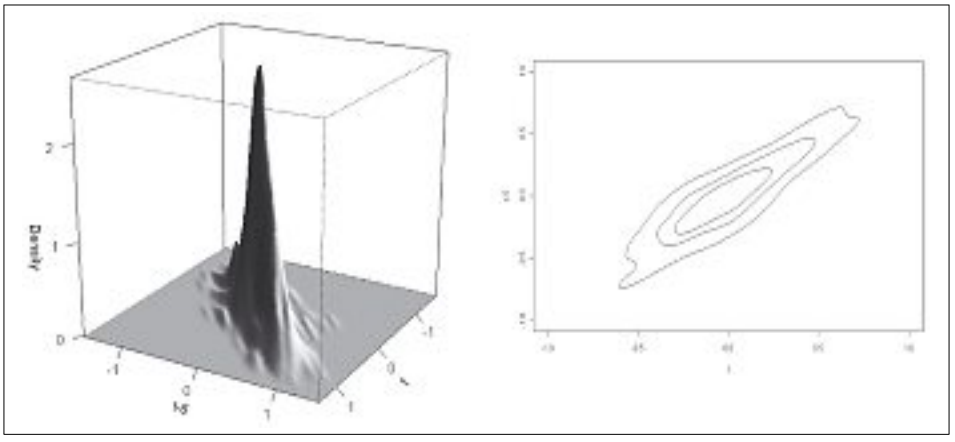
A contour plot is also included in figure 5. Each line shows a cut parallel to the X- and Y- axis for different density values. The lines connect, therefore, points with the same densities. We find that the probability mass is concentrated around the positive diagonal and the width of the contour lines is narrow. The low degree of mobility within the distribution is again confirmed.

The stochastic kernel based on the conditioned distribution is presented in figure 6. A large portion of the probability mass remains clustered along the main diagonal over the five-year horizon, and the peak lies along this line indicating a low degree of mobility and a modest change in the regional productivity distribution. But it is important to notice that the degree of mobility is higher than in the case of the non-conditioned distribution (the width of the contour lines is wider) and the bimodality disappears.

To summarize, results indicate low mobility within the agricultural productivity distribution in the observation period. We confirm that regions generally maintain their relative positions in such a way that they tend to end up where they started. Persistence is especially important in the lowest and highest levels of productivity, whereas movements are concentrated in the medium states. This could be interpreted as convergence process has not taken place among regional agricultures or, at least, that this process is being very slow and mainly explained by regions close to the average productivity rather than improvements of the low-productivity regions. This result is compatible with other parametric convergence analyses that find scarce evidence of absolute convergence towards a similar level of productivity (Paci, 1997; Paci and Pigliaru, 1998; Colino and Noguera; 2000; Alexiadis and Alexandrakis, 2008; Sassi, 2010).

In Ezcurra *et al.* (2008 and 2011), the country to which the region belongs, the sector investment and the economic development level of the regions are more relevant than some characteristics of agricultural holdings to explain the observed disparities. At the same time, the authors do not find evidence of the importance of the productive

Figure 6. **Stochastic kernel of the agricultural productivity relative to the cluster average (in logs), (period *t* and *t*-5), 1985-2004**



*Source:* Cambridge Econometrics

specialization. On the contrary, in this paper the empirical analysis shows the great importance of the different socio-economic characteristics when it comes to explaining the dispersion observed in the levels of productivity. The differences observed in the size of the holding, the characteristics of the labour force and the holders and the productive specialization make a significant contribution to explaining the agricultural disparities in productivity.

## 5. Conclusions

The present paper analyses the evolution of regional agricultural productivity under the hypothesis that, in spite of the European integration process and the existence of a common policy on agriculture, productivity differences persist due to differences in 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 on convergence at two levels. First, given that in European agriculture different social and structural patterns coexist, we include these differences in the analysis of convergence. Secondly, we follow a methodological alternative to the traditional convergence approaches. 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.

We have observed no evidence of strong productivity convergence across regions. It is true that the mode of the distribution is around the EU-15 average but the probability mass concentrated around the highest and the lowest levels of productivity is significant as well. Convergence is slow and is accompanied by some polarization.

Given that regions are not likely to change their relative positions in terms of productivity, disparities across the EU are large and persistent. The highest mobility is

observed in the medium-high productivity regions, while persistence is higher in the extremes of the distribution, particularly in the lowest extreme. Therefore, economies tend to be concentrated near the mean values as a result of changes within the distribution, but regions in the extremes of the distribution resist change.

Our analysis reveals that there are ten different types of agriculture in terms of their structural characteristics. Differences in the economic and territorial size, the labour force and the productive specialization are evident and condition the evolution of productivity. The diversity of regional patterns configures a sector in which the less efficient agricultures, with weaker agricultural structures (small economic and physical dimension of holdings, less qualified labour force, more aged workforce, low degree of mechanisation), tend to remain in the lowest position of the productivity ranking. On the contrary, the most developed agricultures have no problems to achieve productivity gains.

Once this heterogeneity is controlled for, distribution is more concentrated around the mean values and the mobility within the distribution is higher. We have observed the important role of the structural characteristics in the productivity dynamics. The main conclusion of the paper is that divergence in agricultural labour productivity across regions will continue if the current differences in structural patterns persist in the future.

If we consider agricultural productivity convergence as a factor reflecting a deeper market integration, this paper seems to confirm that such integration does not exit. The high persistence in the agricultural productivity distribution could be associated with the existence of non-competitive agricultures with high CAP market support. In this sense, policy makers should take into account the different territorial characteristics when it comes to defining the CAP, given the spatial implications of this policy. Territorial strategy should take precedence over the sector approach. The structural and rural development policies based on supporting farmers to increase the economic dimension of holdings and take advantage of the endogenous potential may be a suitable form of action. Undoubtedly, an R&D policy leading to innovation and productivity growth would be an important pillar of this strategy.

Finally, concerning future research, the incorporation of the regions of the last enlargement towards the East of Europe would enrich the analysis. For this purpose it is necessary to extend the period of study. Once data are available, studies that consider the East regions will be crucial to evaluate the impact of the enlargement on agricultural imbalances. The high share of agricultural activity in the East countries and their relative low levels of productivity could result in differences being maintained or even increasing. The analysis of this issue will also help to the future reconsideration of the instruments of the sector's policy.

On the other hand, it would be desirable to find models or techniques leading to some new and interesting results. The fact that the less productive regions tend to be located always in the same countries, which also holds true for the most productive ones, makes one suspect that results could present spatial dependence. The use of spatial econometric techniques could be a good option to introduce this possibility into the models.

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## APPENDIX A: SELECTED REGI0NS

**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-Ardenne
FR22 Picardie
FR23 Haute-Normandie
FR24 Centre
FR25 Basse-Normandie
FR26 Bourgogne
FR3 Nord-Pas-de-Calais
FR41 Lorraine
FR42 Alsace
FR43 Franche-Comté
FR51 Pays de la Loire
FR52 Bretagne
FR53 Poitou-Charentes
FR61 Aquitaine
FR62 Midi-Pyrénées
FR63 Limousin
FR71 Rhône-Alpes
FR72 Auvergne
FR81 Languedoc-Rouss.
FR82 Prov-Alpes-Côte 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
PT15 Algarve
PT16 Centro
PT17 Lisboa
PT18 Alentejo
PT2 Acores
PT3 Madeira

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

**SWEDEN (NUTS 2)**
SE11 Stockholm
SE12 Ostra Mellansverige
SE21 Smaland med oarna
SE22 Sydsverige
SE23 Vastsverige
SE31 Norra Mellansverige
SE32 Mellersta Norrland
SE33 Ovre Norrland

**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