AGRICULTURAL PRODUCTIVITY IN THE EUROPEAN REGIONS: TRENDS AND EXPLANATORY FACTORS

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Agricultural Productivity in the European Regions:

Trends and Explanatory Factors

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Abstract

This paper examines the spatial distribution of agricultural productivity in the European regions for the period 1990-2000, using a twofold descriptive and explanatory approach, which allows us to overcome the drawbacks of conventional convergence analysis. The spatial distribution of agricultural productivity is summarized in a regional typology that enables us to evaluate the different trends of the European regions. The various inequality indices and estimated density functions reveal a decrease in regional agricultural productivity disparities, while intra-distribution mobility is found to be relatively limited during the study period. Additionally, the results obtained from the regression analysis are in line with those obtained at the national level. Finally, our non-parametric approach allows us to assess the role of variables such as economic development, agricultural structure and productive specialization in the dynamics of the distribution under analysis.

Key words: Agricultural productivity, regions, European Union.

JEL code: Q10, R11, R12.

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1. Introduction

Recent years have seen the publication of a great a number of works using a variety of approaches to analyze territorial imbalances in per capita income or aggregate productivity within the European Union[1]. Various factors contribute to the level of interest raised by this issue. Not least among them are the major developments that have taken place in economic growth theory over the last twenty years, coinciding with the advent of endogenous growth models during the eighties. Another is the need to reduce development gaps across the various European regions, an issue that inspired some of the basic principles upon which the Union was founded and came even more to the fore with the signing of the Single Act and the Maastricht agreements. Indeed, one of the specific assumptions of the European integration program is that it will drive the growth of all Member States, and thereby lead to economic and social cohesion[2].

This situation has given rise to a vast literature on regional convergence-divergence and the role played by European economic integration in general and European regional policy in particular. On this subject we can recommend, with no pretension of exhaustiveness, the works of Barro and Sala i Martin (1992); Cuadrado (2001); European Commission (2004); Gardiner et al. (2004); Ezcurra et al. (2005) and Ertur et al. (2006), among many others.

A second set of works relating to our frame of reference are the studies of sectoral productivity convergence in the European Union. Some of them address the issue at the regional level but most of the research has been conducted at the national

[1] A review of the main conclusions reported in this literature can be found in Armstrong (2002) and Eckey and Türck (2006).

[2] Article 2 of the Treaty of the European Union specifically states that: “the Community mission will be to promote (...) the harmonious, balanced and sustainable development of economic activities, sustained growth (...), and a high degree of convergence of economic performance (...)”.

level. By far the most widely studied sector is industry, where researchers have focused on trends in the specialization and concentration of manufacturing activities, in order to compare the predictions for economic integration arising from the neoclassical international trade theories and the so-called New Economic Geography (Krugman, 1998)

In relation to agriculture, the first reference worthy of note is the annual publication edited by the European Commission, which analyses the situation from a community standpoint[3]. In addition, there is a vast number of works focusing on national agricultural performance and trends within the EU, from a number of different approaches, see e.g. Ritson and Harvey (1997), Buckwell et al. (1997), Schimmelpfenning and Thirtle (1999), Burrel and Oskam (2000), Gutierrez (2000), Ball et al. (2001), Wichern (2004), and Rezitis (2005), among others.

There are, however, very few studies of trends in regional agriculture in Europe as a whole, probably owing to the lack of statistical data. This is all the more surprising in view of the large amount of funds that have been allocated to the CAP over the last four decades[4]. Thus, a study carried out for the Commission by the RICAP Group of agricultural economists was "beset by many difficulties of which the most important was without doubt the lack of centralized information both on trends in agricultural products and economic performance of regional agriculture within the Community" (cited by Shucksmith et al. 2005, 3). Nevertheless, over the last few years a number of studies has emerged, among which we might mention Shucksmith et al. (2005); Castillo and Cuerva (2006) and Ezcurra et al. (2006). These contributions show that the development of regional policy since the 1990s and the merging of agricultural and

[3] See in the web page http://europa.eu.int the site of the Common Agricultural Policy (CAP, henceforth)

[4] This policy, the ultimate aim of which was to increase productivity in European agriculture, in line with the provisions of the Treaty of Rome, used around 60% of the European Union budget between 1990 and 2000. Nevertheless in 2006 the share of CAP expenditure is 46.5%.

regional policies within the new framework of economic and social cohesion have increased concern for the spatial effects of community policies as a whole (European Commission 2001 and 2004). Shucksmith et al. (2005) is worth mentioning as the key contribution to redress the lack of studies on European regional agriculture. This work is one of the results of the ESPON project. (European Spatial Planning Observation Network)[5].

It is against this background that this paper analyses, in some detail, the regional distribution of agricultural productivity in the European Union during the period 1990-2000 using both a static and a dynamic framework. We also aim to explain regional agricultural productivity according with others papers which analyze agricultural productivity at international level. Thus, despite certain limitations, we contribute new evidence, and use a methodological approach seldom used in the cited literature.

The content of the paper is organized as follows. Section 2 presents the data and methodology. In the section 3 we analyze the spatial distribution of productivity in the agricultural sector in the European Union using a regional typology. Section 4 examines the distribution dynamics. Then, in section 5, we investigate the role played by a range of variables in explaining existing territorial imbalances in the European farming sector. We finish by presenting the main conclusions in the last section.

2. Data and methodology

The data used in the paper are taken from the Cambridge Econometrics regional database. The data provided by Cambridge Econometrics are based mainly on the information on the agricultural sector supplied by Eurostat, which is, however, seriously lacking in some respects, especially when it comes to data relating to the early 1980s

[5] For more information see the web page of ESPON (http://www.espon.eu/)

(Shucksmith, et al. 2005). Taking into account data availability, we have considered the agricultural productivity of 99 territorial units, mainly NUTS-2 regions[6] (see Appendix 2), for the period 1990-2000 calculated from data on gross value added at market prices in real terms and agricultural employment figures. Meanwhile, in order to perform the explanatory analyses, we have used data drawn from the Structure of Agricultural Holdings Surveys (1990 and 2000) from Eurostat.

As mentioned above, the study variable is agricultural productivity, measured in terms of labor factor productivity or, more specifically, gross value added per worker[7]. The use of this variable is the subject of some controversy in the literature. The OECD (2001), for example, suggests the possibility of using different productivity measures, one of which would be the single factor productivity measure based on value added. They identify the main drawback of this as the fact that "labor productivity is a partial productivity measure and reflects the joint influence of a host factors. It is easily misinterpreted as technical change or as the productivity of the individuals in the labor force" (OECD 2001, 15). In the same vein, Ruttan (2002) claims that an analysis of agricultural productivity based on this ratio constitutes an initial stage that falls short of capturing in detail the complexity of the agricultural production process. This author states that the second stage of the analysis of agricultural productivity is the estimation of total factor productivity. There is a vast literature on this issue, especially at the country level, some of the main works being Arnade (1998); Ball et al. (1999); Ball et al. (2001); McErlean and Wu (2003); and Coelli and Rao (2005). Some of the studies

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[6] NUTS is the French acronym for 'Nomenclature of Territorial Units for Statistics', a hierarchical classification of sub-national spatial units established by Eurostat. In this classification, NUTS-0 corresponds to country level and increasing numbers indicate increasing levels of sub-national disaggregation.

[7] As an additional variable, we have also used gross value added per hours worked, as is usual in other works, but, since the results were so similar to those using gross value added per worker, we based our findings on the latter.

cited above also examine productivity convergence across regional and national agricultures.

Some authors, however, claim that both partial and total productivity measures can and should be used, since there are advantages and disadvantages to both types. Eldmann (2002), for instance, identifies the key advantages of partial measures as ease of calculation and readability, and the main drawback of total factor productivity measures as the strong demands they make on data availability. The latter is also cited by Schreyer and Pilat (2001) as one of the factors to be taken into consideration when deciding which productivity measure to apply. Sargent and Rodríguez (2001) claim that the "choice should depend on several factors, including the time period of interest, the quality and comparability of the capital and the growth model assumed" (Sargent and Rodríguez 2001, 12) and suggest that if the intent is to examine trends over a period of less than a decade or so, then labor productivity is a better guide, and that TFP is more useful if the analysis is focused on long round trends in the economy.

With these recommendations in mind, and given the difficulty of finding reliable data at European regional level to compute total factor productivity, we decided to use the afore-mentioned partial measure of agricultural productivity. Moreover, our focus is not the measure of agricultural productivity per se; our main objective is to examine the way in which regional disparities in European agriculture have evolved between 1990 and 2000. Given our chosen methodological approach, it is quite feasible to use this variable. The above notwithstanding, and as noted earlier, we are aware of the limitations of using a partial measure of agricultural productivity.

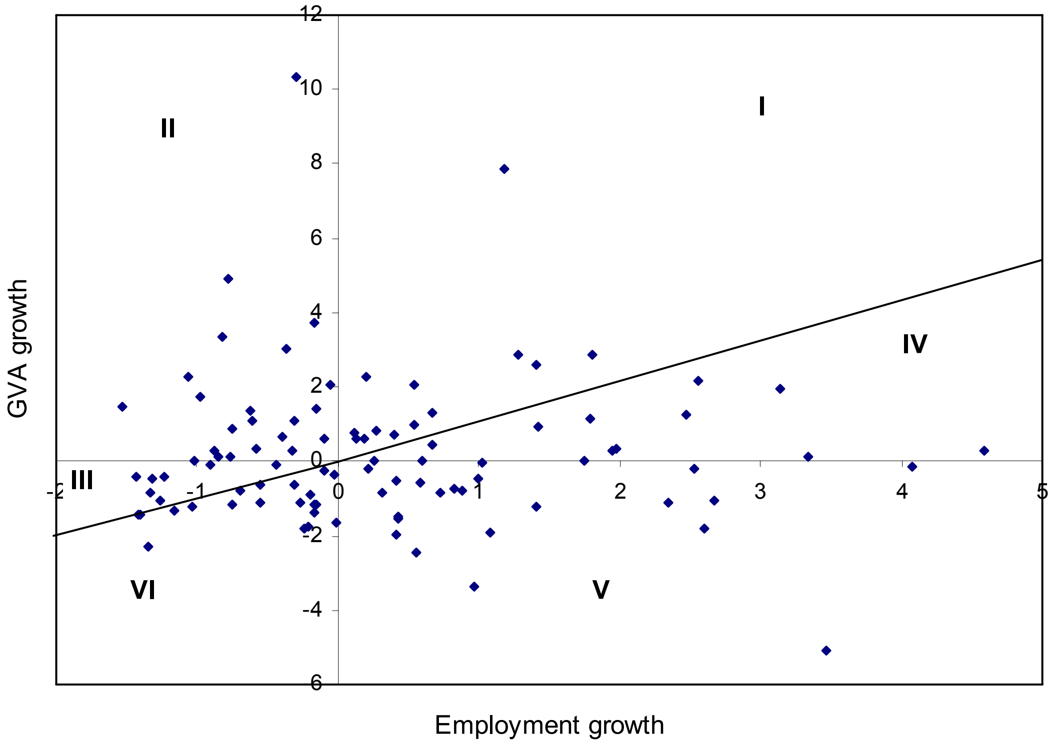
With respect to the methodology, the few existing studies of regional disparities at the sectoral level in the European context apply the concepts of sigma convergence and beta convergence introduced by Barro and Sala-i-Martin (1992), combining the information provided by various dispersion statistics with the estimation of convergence equations. However, as Quah (1993, 1996a,b) has repeatedly pointed out, not only does this approach raise a number of econometric problems, it also fails to capture a series of potentially interesting issues relating to the dynamics of the distribution in question. In particular, this type of analysis provides only a partial view of the observed distribution, since it neglects to consider, for example, the fact that the various regions may shift their relative positions over the study period; thus it completely ignores the possibility of intra-distribution mobility. The standard convergence approach also ignores the fact that a reduction in dispersion in the distribution under consideration may be compatible with a process of polarization into several internally homogeneous regional clusters (Anderson, 2004). In order to overcome the limitations of conventional convergence analysis, we have opted in this paper to use the non-parametric approach proposed by Quah (1996a, b) to examine the dynamics of the entire cross-sectional distribution over time.

3. Productivity, gross value added and employment growth: A regional typology

Variations in regional agricultural gross value added per worker over time are the result of changes in gross value added and/or employment across the different regions. Since agricultural productivity growth is the outcome of various types of adjustment processes, its distribution may be spatially uneven.

At national level, Wichern (2004) concludes that the main cause of increase in agricultural labor productivity in the European Union is the outflow of labor. In order to investigate this issue at regional level, we aim to perform a joint analysis of the regional growth rates of agricultural productivity, gross value added and employment, using the methodology proposed by Camagni and Capellin (1985). The main advantage of this approach lies in the fact that it not only helps us to understand how agricultural productivity in each region has evolved in relation to the community average, but also provides us with information about the role played in the process by changes in gross value added and employment[8]. In fact, it is by combining growth rates corresponding to the three above-mentioned variables throughout the period 1990-2000 that we are able to obtain the regional typology shown in Figure 1.

Figure 1: Labor productivity, gross value added and employment growth in the agricultural sector: A regional typology.



Note: The straight line captures combinations of gross value added and employment growth rates that generate a productivity growth rate equal to the sample average.

Thus, gross value added in European Union agriculture has grown by 1.11%, while employment has declined by 2.25% over the course of the eleven years considered. The immediate reflection of this can be seen in the agricultural productivity

[8] To avoid bias in the results due to the uncertain nature of agricultural production, the 1990 values are estimated from the mean of the values for 1990-91-92 and the 2000 values are estimated from the mean of the values for 1998-99-00.

trend, which shows a rate growth of 4.32%. This trend is similar to that observed between 1980 and 1990. In this period gross value added increased by 1.05%, employment decreased by 2.0% and productivity grew by 3.81%. The most notable difference between the two periods lies in the fall in employment which was greater in the decade that concerns us in this paper.

At regional level the situation varies according to the different patterns of gross value added and employment in each region. If we compare regional and general trends, we find the regional typology shown in Figure 1. We have added some complementary variables from each group presented in Table 1. The geographical situation of this regional typology can be seen in Figure 2.

There are 49 regions in which agricultural productivity growth during the sample was higher than the community average. The particular situation varies across different types of regions:

- The type I regions include 13 with productivity growth (5.09%) above the community average, due to a higher increase in gross value added in all groups (2.55%) and less reduction in employment compared to the community average (-1.69%). Table 1 shows that this set of regions account for around 10% of the total area and population, and 9.26% of agricultural gross value added. It should be noted; moreover, that gross domestic product per capita in the regions in question is below average (91.05). They are widely dispersed geographically speaking, and include not only areas such as the French regions of Bourgogne, Aquitaine and Alsace, the Italian regions of Lombardy, Trent and Tuscany, the UK territories of Wales, Northern Ireland and West-Midlands, and Luxembourg and the Balearic Isles, where agriculture is economically irrelevant, but also the Greek regions of Anatoliki and Voreio Aigao where it is a key factor in the local economy.

Table 1:Characteristics of the regional typology.

Regions	**Type I**	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**
Productivity growth (%)	5.09	7.69	5.72	2.36	1.15	3.50
Gross value added growth (%)	2.55	2.54	0.27	1.77	0.13	0.03
Employment growth (%)	-1.69	-2.91	-3.47	-0.49	-0.94	-2.57
Area (%) [(a)]	9.53	21.49	17.06	16.38	21.36	14.17
Population (%) [(a)]	10.27	17.66	18.92	16.27	22.12	14.76
Gross value added (%) [(a)]	9.26	17.50	16.03	18.50	22.26	16.46
Employment (%) [(a)]	7.30	21.39	26.70	13.30	18.55	12.76
Level of GDP per capita [(b)]	91.05	106.79	107.70	101.20	89.41	102.92

Note: [(a)] Values in 1990. [(b)] Sample average equal to 100. GDP: Gross Domestic Product

-The type II regions include 22 that have achieved gross value added growth rates above the European average during the period analyzed (2.54%), though they are above average in terms of regional loss of employment (-2.91%). Thus, their productivity growth is the highest of all the groups (7.69%). This group accounts for roughly 21% of agricultural workers and the geographical surface area. They have a 17.5% share in total population and agricultural gross value added, and their gross domestic product per capita is above the European Union average (106.79). They also are geographically dispersed, and include areas such as Denmark, three regions in the North of Germany, the South-West of England. Also belonging to this group are four regions in the central-eastern part of Greece and three Spanish regions, including La Rioja, which has one of Spain's highest agricultural productivity levels.

- Type III groups 14 regions with a very slight increase in gross value added (0.27%), and a high adjustment in employment (-3.47%). Thus the productivity growth rate is above the European Union average (5.72%). This group presents the highest level of gross domestic product per capita (107.6). It is worth noting that these regions have the highest share of employment in agriculture (26.7%). The others indicators range between 16% in agricultural gross value added and 18.92% in total population. In terms of geographical location, most of these regions belong to Germany, Italy and Portugal. There are also one French and one Spanish region.

Meanwhile, the different situations faced by the 50 regions with a productivity growth rate below the European average are as follows:

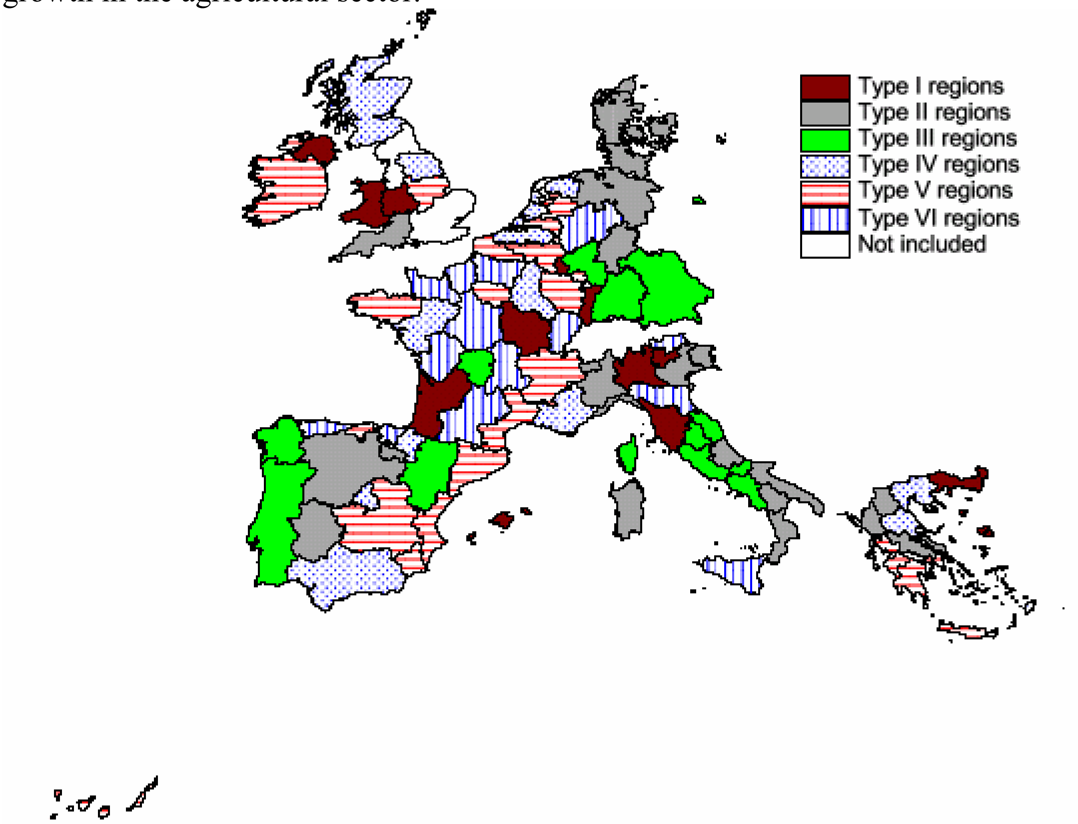
- The type IV regions include 14 in which the 2.36% productivity growth rate is the result of very little variation in the employment rate (-0.49%) and an increase of 1.77% in agricultural gross value added. This group has an 18.5% share in gross value added, and 21% in total population and geographical surface area. Their level of gross domestic product per capita is very close to the European average (101.2). The regions of this group are geographically located in six European countries, Belgium, Greece, Spain, France, Netherlands and United Kingdom.

- The type V regions include 22 with very little growth in gross value added (0.13%), some loss of employment (-0.94%) and a productivity growth rate of only 1.15%, well below the European Union average for the eleven years considered. This group is one of the biggest, with 22.26% of the total gross value added, 21.36% of the total surface area and 22.12% of the total population. These regions are also the poorest, as evidenced by their gross domestic product per capita level of 93.25. Geographically, this is one of the most disperse and heterogeneous groups, since it contains Scotland and Yorkshire in the UK, and also the Greek isles of the Aegean, for example.

- The type VI group is formed by 14 regions with a productivity growth rate of 3.5%, based on a reduction in employment (-2.57%) thus gross value added remains stable (0.03%). This group of regions is one of the smallest. It accounts for around 14% of the total surface area and population. Gross domestic product per capita for this group is 94.35, which is below the European average, while their shares in agricultural gross value added and population are 16.46% and 12.76%, respectively. The majority of the regions in this group belong to France, although it also includes some in Italy, Spain and Germany.

The purpose of this section was to illustrate the diversity of agricultural productivity performance. As the reader has had the opportunity to observe, we have observed variations over time in European agricultural productivity, gross value added, and employment trends.

Figure 2: Spatial distribution of labor productivity, gross value added and employment growth in the agricultural sector.



4. The dynamics of the regional distribution of productivity in the agricultural sector

Following on from the above section, in which we analyzed trends in gross value added, employment and apparent labor factor productivity in the various regions considered, we now undertake an examination of regional disparities in the same setting over the period 1990-2000.

In contrast to the procedure adopted in conventional convergence analysis, this paper approaches the issue by calculating a series of indicators traditionally used to study personal income distribution. In particular, it is a well-known fact within this literature that results may differ, at times substantially, according to which measures are used in the analysis. Given the obvious difficulty that arises from the fact that different indicators may give different orderings of the distributions to be compared, it would seem reasonable to check the robustness of our results against different inequality measures. Following this procedure, in this paper we examine regional disparities in European agriculture based on the information provided by the Gini index, G, and the two measures proposed by Theil (1967) within the information theory context, T(0) and T(1). Specifically,

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|y_i - y_j\right|}{2\mu n^2} \tag{1}$$

$$T(0) = \sum_{i=1}^{n}\frac{1}{n}\log\left(\frac{\mu}{y_i}\right) \tag{2}$$

and

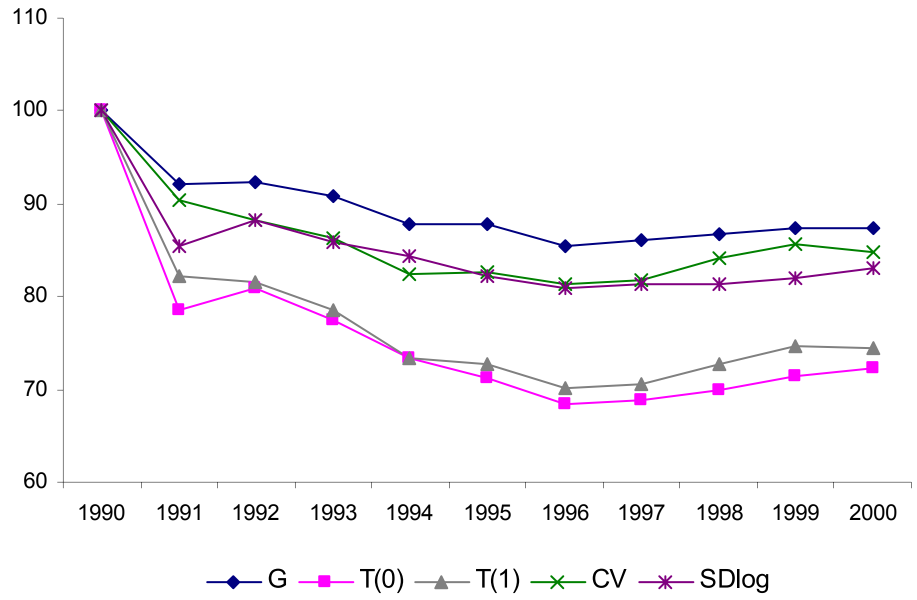
$$T(1) = \sum_{i=1}^{n}\left(\frac{y_i}{\mu n}\right)\log\left(\frac{y_i}{\mu}\right) \tag{3}$$

where y_i and μ denote the gross value added per worker of region i and the average of the distribution in year t, respectively. We also take into account the coefficient of variation, CV, and the standard deviation of the logarithm, SDlog, two measures of dispersion that are common in descriptive statistics and widely used in the convergence literature to capture the concept of sigma convergence (Barro and Sala-i-Martin, 1995).

All the indices selected are independent of scale and size of population and, except for the standard deviation of the logarithm, they all fulfill the Pigou-Dalton transfer principle for the whole definition domain of the study variable (Cowell, 1995)[9].

Figure 3 presents the evolution of the inequality measures just mentioned. The results indicate a decrease in dispersion within the distribution under analysis between 1990 and 2000. Indeed, the various indices fell by between 11 and 27% over the eleven years considered. Nevertheless, this does not imply a uniform decline in disparities over the period. In this respect, it is important to bear in mind that, whatever measure is considered, the observed convergence process was due to the evolution of the distribution during the first half of the nineties. In fact, as can be checked in Figure 3, from 1996, the dispersion of the distribution increases slightly, although not enough to reverse the previous reduction in inequality.

Figure 3: Regional disparities in agricultural productivity (1990=100).



[9] The Pigou-Dalton transfer principle is a property commonly required of inequality measures, under which any income transfer from a rich individual (or region) to a poorer one that does not invert their relative positions must reduce the inequality

It is important to bear in mind, however, that the various measures calculated in Figure 3 do not supply an accurate description of the distribution as a whole (Quah, 1996a, b). For this reason, we proceed by estimating the density functions of the regional distribution of agricultural productivity. In doing so, we follow common practice in the literature and use non-parametric estimation techniques, thus avoiding the need to specify any particular functional form beforehand.

Specifically, we employ an adaptive kernel method with flexible bandwidths (Silverman, 1986). This approach is especially advisable in the present context, since the possibility of varying the bandwidth along the support of the distribution allows us to reduce the variance of the estimates in areas characterized by the presence of few observations, and decreasing the bias of the estimates in areas with many observations. In particular, we use the adaptive two-stage estimator proposed by Abramson (1982) and given by:

$$\hat{f}(y) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h\lambda_i}K\left(\frac{y-y_i}{h\lambda_i}\right) \quad (4)$$

In the above expression K is a kernel function and $\lambda_i = \sqrt{\frac{g}{\tilde{f}(y_i)}}$, where g is the geometric average over all i of the pilot density estimate $\tilde{f}(y)$. The pilot density estimate is a standard fixed bandwidth kernel density estimate obtained with h as a bandwidth. In this study Gaussian kernel functions are used, while the optimum value of h is found following Silverman (1986, 48).

The results obtained by using this methodology are shown in Figure 4[10]. When interpreting this Figure it should be noted that the variable plotted on the horizontal axis represents the normalized rate of agricultural productivity (sample average equal to 100)

[10] Though density functions were estimated for each year of the period analysed, for the sake of brevity, we present in Figure 4 only those of 1990 and 2000. In any event, the rest are available from the authors upon request.

in order to facilitate comparisons, while the associated density appears on the vertical axis. Although, as can be seen, the estimated density functions for 1990 and 2000 are both unimodal, this does not mean that the initial situation remained unchanged during the nineties.

Figure 4: Density function of the regional distribution of agricultural productivity.

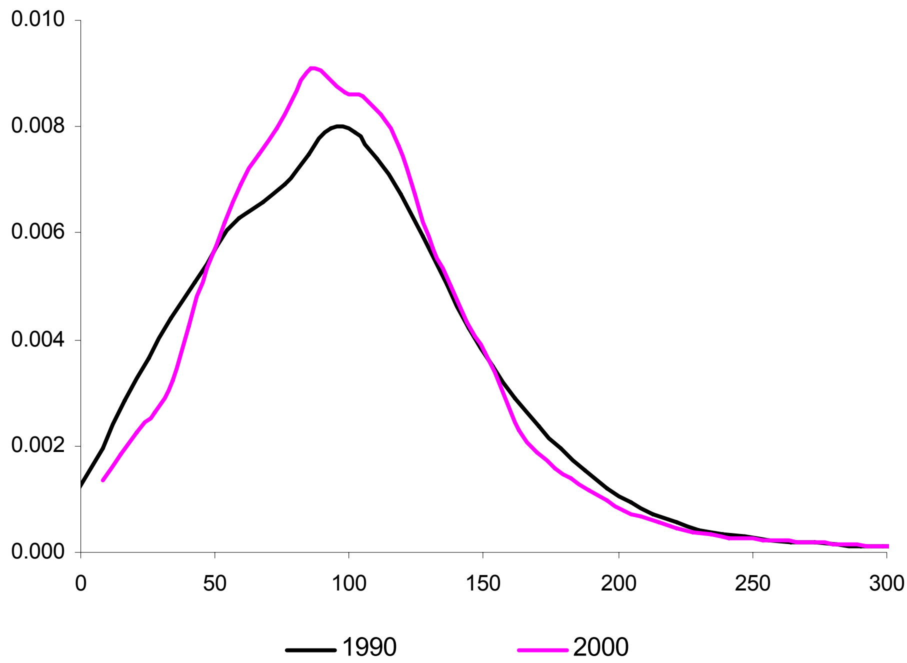


Figure 4 in particular reveals growth over time in the probability mass located around the sample mean due to weight loss at the upper and lower ends of the distribution. In fact, in 1990, gross value added per worker in the agricultural sector ranged between 50% and 150% of the mean in 63% of the regions considered, while eleven years later, in 2000, 71% of the regions had reached that level. It should be noted that these results are consistent with the findings drawn earlier from the information provided by Figure 3.

Having reached this point, however, we should remind readers that the analysis performed so far in this section is based exclusively on the information obtained from a series of cross-sectional observations of the distribution under study. Therefore, it does not take into account the fact that the different economies may over time modify their relative positions in terms of value added per worker in the agricultural sector. To address this shortcoming and to complete the results obtained up to this point, we decided to examine the degree of mobility in the regional distribution of agricultural productivity within the European Union during the period 1990-2000.

Most of the studies that have addressed this issue base their findings on the information provided by discrete transition matrices, obtained by dividing the distribution into a series of exhaustive and mutually exclusive classes. There is a drawback to this approach, however, since the results it yields are sensitive to the way in which the observed distribution is discretised. In fact, different methods may provide different results and even affect the Markov properties of the dynamic process (Bulli, 2001). To address this problem, Quah (1996a) suggests substituting the transition matrix with a stochastic kernel which reflects the probabilities of transition between a hypothetically infinite number of ever-smaller classes (see Durlauf and Quah (1999) for a formal definition). The stochastic kernel can be reached by estimating the density function of the distribution over a given period, $t+k$, conditioned on the values corresponding to a previous period, t. In other words, the joint density functions at moments t and $t+k$ is estimated and then divided by the implicit marginal distribution in order to obtain the corresponding conditional probabilities.

Figure 5 shows the stochastic kernel estimated from the regional distribution of agricultural productivity for five-year transitions[11]. This three-dimensional graph shows how the cross-sectional distribution at t evolves into that observed at $t+5$. In other words, the stochastic kernel gives us, as does a discrete transition matrix, the probability

[11]Gaussian kernel functions are used again, while the smoothing parameter has been selected following Silverman (1986, 86).

distribution of agricultural productivity at $t+5$ for regions with a given value at t. Thus, if the probability mass were concentrated around the main diagonal, the intra-distributional dynamics would be characterized by a high level of persistence in the relative positions of the regions over time and, therefore, low mobility. If, on the other hand, the density is located mainly on the diagonal opposite to the main diagonal, this would indicate that regions situated at either extreme of the distribution had switched their relative positions. Finally, the probability mass could, in theory, accumulate parallel to the t axis around a certain value of the variable under analysis. This would reflect the convergence of regional value added per worker in the agricultural sector throughout the study period. In order to aid interpretation of the graph, Figure 5 also includes the corresponding contour plot on which the lines connect points at the same height on the three-dimensional kernel.

Figure 5: Stochastic kernel and contour plot of the regional distribution of agricultural productivity.

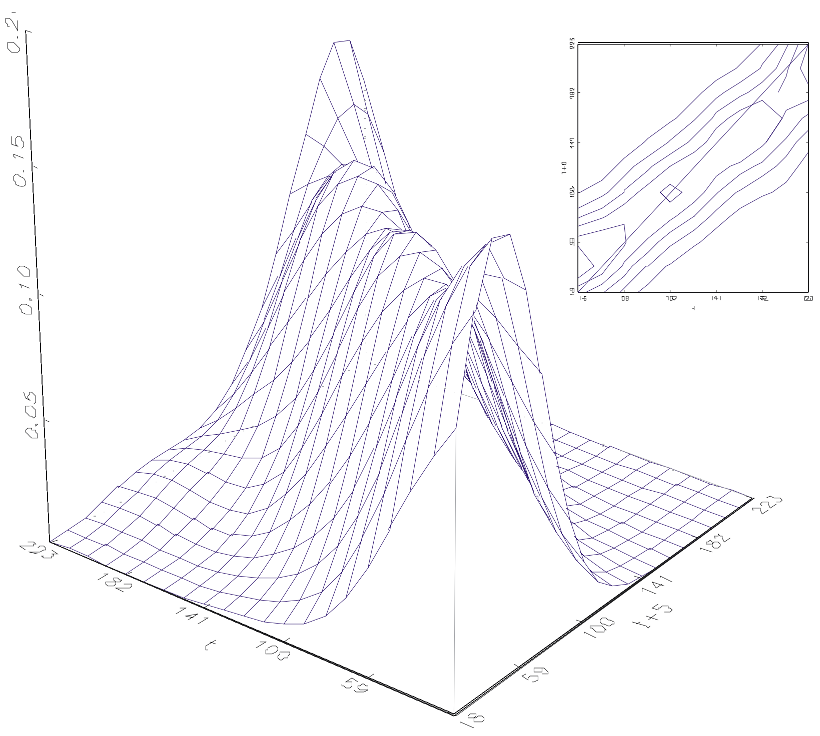


Figure 5 shows that most of the probability mass is concentrated around the main diagonal. As we know, this can be interpreted as evidence of low mobility in the regional distribution of agricultural productivity over the study period[12]. The European regions, therefore, tended on the whole to maintain their relative positions during the eleven years considered in our study. Close examination of Figure 5 shows, however, that several of the regions at the upper and lower ends of the distribution tended to shift towards the mean over time, which allows us to explain the agricultural productivity convergence process detected earlier[13].

5. Explanatory analysis of the regional distribution of agricultural productivity

In order to further complete the results presented so far, we now turn our attention to an examination of the explanatory factors underlying the regional differences in the levels of agricultural productivity in the European Union. Specifically, our aim is to assess to what extent the distribution under consideration is modified by the introduction of different variables in the analysis. In this respect, it is worth mentioning that the choice of the explanatory variables employed in this section **is** based mainly on theoretical considerations, although the final selection is restricted by the availability of reliable statistical data for the geographical setting considered.

Numerous hypotheses have been put forward in the literature regarding the factors that may exert an exogenous effect on agricultural productivity[14]. The most frequently studied variables are those relating to the education level of agricultural workers (Huffman and Evenson, 1992), expenditure in public and private research

[12] In fact, the coefficient of correlation for the regional distribution of value added per worker in the agricultural sector in 1990 and 2000 is 0.890.

[13] In order to test the robustness of these findings, we proceeded to estimate stochastic kernels for different transition periods. Specifically, we considered one-year and ten-year horizons. However, the results, which can be provided by the authors upon request, are in both cases very similar to those just discussed.

[14] See the reviews of the literature on this subject by Ruttan (2002) and Alauddin et al. (2004).

(Huffman and Evenson, 2006; Alfranca, 1998), the existence of agricultural extension services (Arnade, 1998; Coelli et al., 2003), the available public capital (Gopinath and Roe, 1997), the relative quantity of capital and intermediate inputs per unit of labor (Ball et al., 2001), and different price policies (Fulginiti and Perrin, 1998). In the case in hand, lack of available information at regional level limits the scope of our investigation. Taking this into account, the variables considered in this paper, summarized in table 2, are as follows: regional level of economic development, share of agriculture in the regional economy, investment per worker, mean farm size, percentage of participation in land ownership, and a set of dummy variables to capture differences in farm location, farm production specialization and type of farm owner, age and level of dedication to farming, (in the Appendix 1 we present some descriptive statistics of these variables).

Table 2: Explanatory variables considered in the analysis.

Variables
Economic development level
Per capita Gross Domestic Product
(Per capita Gross Domestic Product)^2
Surface in Less Favored Areas (%)
Investment per worker in the agricultural sector
Owner characteristics
Farmer's age
Participation in land ownership (%)
Farm characteristics
Mean farm size
Productive specialization
Gross value added in the agricultural sector (%)
Specialization in grazing livestock
Specialization in field crops

Accordingly, the model proposed to explain the level of agricultural productivity in the regions of the European Union can be expressed as:

$$y_{it} = \alpha + X_{it}\beta + u_{it} \qquad (5)$$

where X is a vector which includes the set of explanatory variables considered, while u is a random disturbance term. The unknown coefficients were estimated by ordinary least squares (OLS) with heteroscedasticity consistent standard errors, using the observations from the 99 regions contemplated during year t ($t = 1990, 2000$). In this context, it is important to note that we did not impose equality restrictions on the coefficients across equations for each of the years considered in the analysis. The reason for not pooling all periods with data availability into a single panel is that standard tests revealed the existence of changes in the effect of the explanatory variables on regional levels of agricultural productivity during the study period.

The estimates of model (5) for 1990 and 2000 are summarized in Table 3. Before discussing the sign and magnitude of the estimated coefficients, it is worth noting that the overall fit achieved by the explanatory variables included in the specification for both years is reasonably high. Furthermore, the degree of collinearity among the regressors, as summarized by the average value of the variance inflation factor calculated for each explanatory variable, is moderate, the values for both 1990 and 2000 falling within the limits considered acceptable by Belsley et al. (1980). This increases our degree of confidence in the estimates of single coefficients.

We also took into consideration the possibility that the variables used to capture the level of development and investment per worker in the agricultural sector may be correlated with the disturbances, and may therefore bias our estimates. In order to investigate this issue, we calculated different Hausman tests, using per capita gross domestic product and investment per worker values lagged five years. In this respect, it needs to be said that the instrument validity of these two variables is supported by their correlation with the original regressors and lack of correlation with the residuals obtained from the OLS estimates (Wooldridge, 2003). In any event, as can be checked in Table 3, the Hausman tests carried out indicate that endogeneity is not a problem in this context. It is also important not to overlook the fact that the presence of spatial dependence in the perturbation term of model (5) could negatively influence the results (Anselin, 1988). For this reason, we proceeded by performing various spatial autocorrelation tests based on the residuals provided by the OLS estimations. Specifically, we calculated the robust versions of the Lagrange multiplier tests for spatial error and the spatial lag model proposed by Anselin et al. (1996)[15]. Nevertheless, the results of these tests led in all cases to the acceptance of the null hypothesis of absence of residual spatial dependence in our model.

Having reached this point, it is worth mentioning that some studies have taken into account the level of regional development as a possible conditioning factor in agricultural productivity. There are several reasons for expecting these two variables to be positively related. As noted by Federico (2005), farmers in wealthier regions or countries are likely to be better educated and less risk-averse and thus better able, quicker and more efficient when it comes to adopting innovations. An additional reason to support the existence of a positive relationship between agricultural productivity and per capita income is that economic growth is positively related to the amount of resources channelled into R&D and infrastructure, both key determinants of agricultural productivity according to the literature (Gopinath and Roe, 1997; McCunn and

[15] To carry out these tests, it is first necessary to define a spatial weight matrix to capture the degree of interdependence between each pair of regions i and j. Following the proposal made by Anselin (1999), in this paper we constructed a row-standardised spatial weight matrix based on the square inverse distance between the centroids of the various regions.

Huffman, 2000; Evenson, 2001). Since data of this kind are not usually available at the regional level, the literature proposes the use of an indirect measure such as per capita income.

Table 3: Explanatory analysis of agricultural productivity.

Variables	**1990**	**2000**
Constant	0.126	0.315
	(0.355)	(0.293)
Per capita GDP	1.601***	0.694*
	(0.499)	(0.398)
(Per capita GDP)^2	-0.745***	-0.289*
	(0.200)	(0.160)
Surface in Less Favored Areas (%)	-0.123*	0.004
	(0.072)	(0.058)
Investment per worker	0.412***	0.472***
	(0.098)	(0.073)
Farmer's age	0.195**	-0.006
	(0.085)	(0.071)
Participation in land ownership (%)	-0.623***	-0.345**
	(0.186)	(0.145)
Mean farm size	0.149***	0.146***
	(0.048)	(0.053)
Gross value added in the agricultural sector (%)	0.157**	0.090*
	(0.078)	(0.049)
Specialization in grazing livestock	-0.236**	-0.152*
	(0.100)	(0.088)
Specialization in field crops	-0.229**	-0.135
	(0.091)	(0.085)
F-Test	31.56***	50.63
Multicollinearity	No	No
Hausman test		
R-LMERR	2.455	0.132
R-LMLAG	2.129	0.651
R-squared	0.795	0.747
Observations	99	99

Notes: Standard errors are in parentheses. The standard errors were calculated using the White (1980) heteroscedasticity consistent covariance matrix estimator. * Significant at 10%; ** significant at 5%; *** significant at 1%. R-LMERR is the robust version of the Lagrange multipliers test for residual spatial autocorrelation. R-LMLAG is the robust version of the Lagrange multipliers test for spatially lagged dependent variable.

The results obtained in our case support this hypothesis, since the estimated coefficient has a positive sign and is statistically significant for both years. Thus we find support for the empirical evidence obtained at the national level, by authors such as Alauddin et al. (2004), who, using data for 111 countries, find that per capita income has a positive effect on agricultural productivity. The same conclusion is reached in a study performed by the European Commission (European Commission, 1994) using regional data, although, in this case, the relationship is found to weaken as regional growth increases. To capture this type of behavior in our sample, the squared per capita income term was also included in the regression, the result being similar to that obtained in other applications, since the estimated coefficient on this term is negative and also statistically significant.

In the European Commission study cited above, it was posited that, given the weakening of the relationship between the two variables as economic growth increases, agricultural productivity may, in later stages of the economic development process, respond more strongly to other factors, natural conditions in particular. In the literature, natural factors are captured by means of variables such as soil quality (Fulginiti and Perrin, 1998) or rainfall (Mundlak et al., 1997) which is used to capture availability of water resources, the scarcity of which is becoming a major constraint on agricultural productivity growth (Ruttan, 2002). As highlighted by McCunn and Huffman (2000), climatic conditions can a have a major impact on the agricultural production process. Craig et al. (1997) and Alauddin et al. (2004) also include variables of this sort in order to assess the relative importance of the natural and economic environment in explaining agricultural productivity differentials.

This information was unavailable in our case, but it can be proxied by the percentage of farms located in less-favored areas, where agriculture is hampered by permanent natural handicaps leading to lower production with the same amount of input factors, and thus lower productivity rates. A dummy variable was defined to divide regions into two groups according to the percentage of agricultural land located in less-favored areas (over or under 70%). The estimated coefficient for 1990 is negative and statistically significant, thus supporting the hypothesis advanced earlier and the results obtained in previous studies (European Commission, 1994). In 2000, however, the coefficient lost all significance.

The literature also includes a wealth of studies (Ball et al. 2001 y 2004; Craig et al. 1997) analyzing the relationship between volume of capital per worker and agricultural productivity. It is generally argued that this relationship will be positive, since it is assumed that the higher the amount of capital, the more easily the farmer will be able to afford to purchase advanced technological equipment, which will permit him to increase his productivity (the hypothesis is that technological information is embodied in this factor of production). In our case, although no measure of capital per worker was available, we proxied it with investment per worker over the preceding 5 year period. The results confirm these hypotheses, since the estimated coefficient shows that the more investment that goes into a region, the higher its agricultural productivity.

Age is a variable that is commonly taken as a proxy of management skill and is usually considered among farmers' socio-demographic characteristics in technology adoption studies. In the majority of cases (Gloy and Akridge, 2000; Soule et al., 2000; Barham et al., 2004) age is understood to be indicative of farmers' aims and motivations, which will depend on the stage in the life-cycle of the farming family. Thus the relationship between age and technology adoption is expected to be negative, given that older farmers have a shorter planning horizon and are unable to take advantage of the long-term benefits of any technology they may adopt. By the same token, younger farmers can be expected to use the most advanced technological equipment and therefore to achieve higher productivity levels. In other contributions to the literature, however, Alauddin et al., 2004) age is interpreted as a variable representing experience and lifetime skills, and thus older farmers are assumed to be better skilled and therefore to present higher productivity levels. With the available data, we decided to include a dummy variable that takes a value of 0 when more than 10% of the region's total number of farm owners (measured in Annual Work Units) is under the age of 35. The result for 1990 is again significant, revealing the existence of a positive relationship between productivity and the percentage of young farmers.

Another variable that may be related to the quality of human capital and optimal resource management incentives, and thereby to productivity, is the farm owner's level of dedication to farming. It is believed that the higher the percentage of his working day that is dedicated to farming, the more closely a farmer's income will depend on farm performance. This leads us to assume a priori a positive relationship between dedication and productivity, such that regions where a high percentage of farm owners give only marginal dedication to farming should present lower productivity levels. To take this aspect of the issue into account, we use a dummy variable that takes a value of zero when farming units whose owners give full-time dedication to farming make up less than 50% of the total and a value of one otherwise. Since the estimated coefficients did not prove to be statistically significant, however, this variable was not included in the chosen model.

Moreover, a negative relationship between productivity and the use of "non-own" input factors was predicted a priori. Because it is not their own property, farmers operating on rented land may be less conscientious in looking after it or using optimal resource management practices (Llewelyn and William, 1996) and may therefore obtain poorer results. But, as Kariagiannis and Sarris (2005) suggest, increasing the portion of rented land may be a potential way for farmers to achieve the technically optimal scale and improve scale efficiency and productivity. This possibility was taken into account by including a variable to capture the percentage of farmer-owned agricultural land. The regression coefficient is statistically significant for both years, showing a negative relationship between the two variables, which lends support to the hypothesis put forward by Kariagiannis and Sarris (2005).

When it comes to farm size, the expected relationship with productivity is positive, due to the presence of scale economies. This assumption is not always fulfilled, however. This relationship is one of the most widely studied throughout the literature, despite the lack of any conclusive findings (see the review by Alvarez and Arias, 2004). One of the most hotly debated issues arising from this is the choice of variable to represent farm size (Lund and Price, 1998). Koester (2005) suggests farm sales value or added value per farm as the best indicators. In our case, we also opt for a farm output measure, namely, the economic size of the holdings measured in European Size Units (ESU) (one ESU corresponds to a standard gross margin of 1,200 euros). The estimated coefficient for both years is positive and statistically significant, which confirms the possible existence of economies of scale in European Union agricultural production processes.

An additional possibility to be considered is that certain agricultural activities may be more productive than others (Helfand and Levine, 2004). This means including a series of additional variables in the regression.

First, we account for the contribution made by gross value added in agriculture to regional gross value added, in order to reflect varying degrees of specialization. This variable may have either a positive or negative effect. In the former case, it is assumed that greater specialization in agricultural production may be due to a greater effort on the part of the agents involved, in which case efficiency and productivity will be increased. In addition, the actual specialization process may involve greater investment in the sector, leading to the introduction of technology. Another possibility, however, is that greater specialization in this sector may come about as a result of regions being unable to attract other types of activities. As a result of low growth, moreover, agriculture may also account for a large share in the economies of such regions. The results show that the regions most highly specialized in agricultural production are more likely to obtain the highest levels of agricultural productivity. Thus, we obtain an estimated positive effect of specialization, possibly associated with the introduction of new technology.

Second, the quality of the results may differ according to the type of agricultural production. Two dummy variables were therefore included to take into account the productive specialization of the primary sector. The first of these takes a value of 1 for regions where the majority of holdings specialize in livestock grazing and zero otherwise. The second takes a value of 1 for regions where the majority of holdings specialize in field crops. The reference group therefore is formed by all the remaining regions (specialized in permanent crops, horticulture, the raising of grain-eating livestock and mixed farming). The estimated coefficients for the first of these two dummy variables are negative and statistically significant for both years, therefore specialization in livestock grazing gives poorer results in terms of productivity. Similar findings are obtained for regions specializing in field crops, although the estimated coefficient is statistically significant only for 1990.

Before continuing, however, it is necessary to point out that the estimated regression coefficients in our model reveal the average effect of the different explanatory variables on the agricultural productivity level of a single representative economy, with no reference at all to their influence on the entire cross-sectional distribution under consideration (Quah, 1996a). For this reason, and following the strategy adopted by Cheshire and Magrini (2000) and López-Bazo et al. (2005) in a different context to that contemplated in this paper, we continue by simulating various virtual distributions from the coefficients estimated in Table 3, assuming the absence of regional differences in 1990 and 2000 in each of the different variables included in our analysis.

The various virtual distributions thus defined can be interpreted as that part of the actual distribution of the regional agricultural productivity that remains unexplained by the existing disparities in each of the variables contemplated. Thus, if the variable in question had no effect on the actual distribution, then the actual and the virtual distribution should coincide. On the contrary, the conditioning variable contributes to explain the inequality observed when the degree of dispersion in the virtual distribution is lower than that in the actual one. In any event, it is worth noting that, unlike other conditioning exercises proposed in the literature (Quah, 1996c; Overman and Puga, 2002), these virtual distributions allow us to consider simultaneously the effect of all the factors included in our study.

Before discussing the results of this analysis, it should be mentioned that, in order to facilitate interpretation, we group the various explanatory variables into four categories (see Table 2 for further details): level of development, owner characteristics, farm characteristics and productive specialization.

Figures 6, 7, 8, and 9 (see Appendix 3) show the density functions estimated by means of the methodology employed in the preceding section for each of the various virtual distributions generated for the four categories considered. In order to facilitate comparisons, the different Figures also include the density functions of the regional distribution of agricultural productivity estimated previously for 1990 and 2000 (Figure 4).

According to our results, regional development differentials are the most important factor when it comes to explaining the degree of dispersion in the regional distribution of agricultural productivity over the study period. In this respect, Figure 6 shows that, when regional development is conditioned out, the distribution clearly becomes more concentrated around the sample average than in the actual distribution both in 1990 and 2000. By contrast, as can be checked in Figures 7 and 8, the role played in this context by owner characteristics and farm size is weaker. Thus, although the corresponding virtual distributions are somewhat more concentrated than the actual one, these factors are only partially able to explain the characteristics of the regional distribution of agricultural productivity. In fact, in the case of owner characteristics, the differences between the virtual and the actual distribution decreased over the sample period. Finally, it should be noted that that Figure 9 indicates that differences in productive specialization do not contribute to explain the observed disparities in the study variable across the European regions.

6. Conclusions

In this paper we have described and explain the regional distribution of agricultural productivity in the European Union between 1990 and 2000. Our results are, in general, comparable to those obtained in the literature, but we contribute new regional evidence with, in some cases, a new methodological approach.

The findings obtained show the spatial distribution of agricultural productivity and its evolution to be highly complex. Six types of region are identified according to their different gross value added and employment trends. In overall terms, agricultures situated in the North of European Union show better results than those located in the South. Our findings also show that the main source of productivity growth is the continuous decline in employment, which confirms the Wichern's (2004) hypothesis at the regional level. The analysis carried out reveals that regional disparities decreased during the study period, as a consequence of the increase in the probability mass located around the sample average. Nevertheless, the estimated stochastic kernel shows a low level of intra-distribution mobility during the period in question.

The standard explanatory analysis points to the positive relation between agricultural productivity and the level of economic development, investment per worker and farm size. In addition, we found a negative relation between agricultural productivity and the share of less favored areas, farm owner's age, and the percentage of farmer-owned land on the holding. In order to complete these results, we considered the role played by the different explanatory variables when it comes to explaining the level of dispersion in the distribution as a whole. In this respect, our analysis reveals that the key role played by the variables grouped under economic development level. The owner and farm characteristics make a less significant contribution to explaining regional agricultural disparities in productivity.

Finally, concerning future research, it is necessary to improve our measure of productivity, using Total Factor Productivity estimations if the data are available. Another question is to extend the period and the regions of study. If that is done, it will be possible to compare our findings with the wide literature devoted to the analysis of the evolution of this variable at national level or at regional level within countries. It will also be necessary to carry out analyses at the regional and sectoral levels in the European Union to understand the patterns of regional economic disparities and the role played by the different sectors in European regional growth processes. Such research is all the more crucial under the new European Union with 27 member states, in which regional disparities will increase dramatically and social cohesion will become a top priority for the European Regional Policy.

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Appendix 1

Descriptive statistics of the variables used in the analysis

	1990		2000	
	Mean	Std. Dev.	Mean	Std. Dev.
Agricultural productivity	19,443.4	11,193.3	28,082.8	13,714.5
Per capita GDP	14,523.9	5,423.3	17,113.8	6,349.2
Investment per worker	5,017.1	3,136.9	8,066.1	4,694.1
Participation in land ownership	65.25	18.57	60,72	19,73
Mean farm size	17.01	15.12	28,03	25,16
Gross value added in the agricultural sector	5.24	4.31	5,08	4,31
Surface in less favoured areas (*)	37.4		34.3	
Farmer's age (*)	50.5		54.5	
Specialization in grazing livestock (*)	36.4		36.4	
Specialization in field crops (*)	19.2		19.2	

(*) The values for these dummy variables indicate the percentage of regions where the variable takes a value of 1.

Appendix 2

The 99 European Union regions considered in the paper are:

Vlaams Gewest (BE2)
Région Wallonne (BE3)
Baden-Württemberg (DE1)
Bayern (DE2)
Berlin (DE3)
Hessen (DE7)
Niedersachsen (DE9)
Nordrhein-Westfalen (DEA)
Rheinland-Pfalz (DEB)
Saarland (DEC)
Schleswig-Holstein (DEF)
Denmark (DK)
Anatoliki Makedonia (GR11)
Kentriki Makedonia (GR12)
Dytiki Makedonia (GR13)
Thessalia (GR14)
Ipeiros (GR21)
Ionia Nisia (GR22)
Dytiki Ellada (GR23)
Sterea Ellada (GR24)
Peloponnisos (GR25)
Attiki (GR3)
Voreio Aigaio (GR41)
Notio Aigaio (GR42)
Kriti (GR43)
Galicia (ES11)
Principado de Asturias (ES12)
Cantabria (ES13)
País Vasco (ES21)
Navarra (ES22)
La Rioja (ES23)
Aragón (ES24)
Comunidad de Madrid (ES3)
Castilla y León (ES41)
Castilla-la Mancha (ES42)
Extremadura (ES43)
Cataluña (ES51)
Comunidad Valenciana (ES52)
Illes Balears (ES53)
Andalucia (ES61)
Región de Murcia (ES62)
Canarias (ES7)

Île de France (FR1)
Champagne-Ardenne (FR21)
Picardie (FR22)
Haute-Normandie (FR23)
Centre (FR24)
Basse-Normandie (FR25)
Bourgogne (FR26)
Nord - Pas-de-Calais (FR3)
Lorraine (FR41)
Alsace (FR42)
Franche-Comté (FR43)
Pays de la Loire (FR51)
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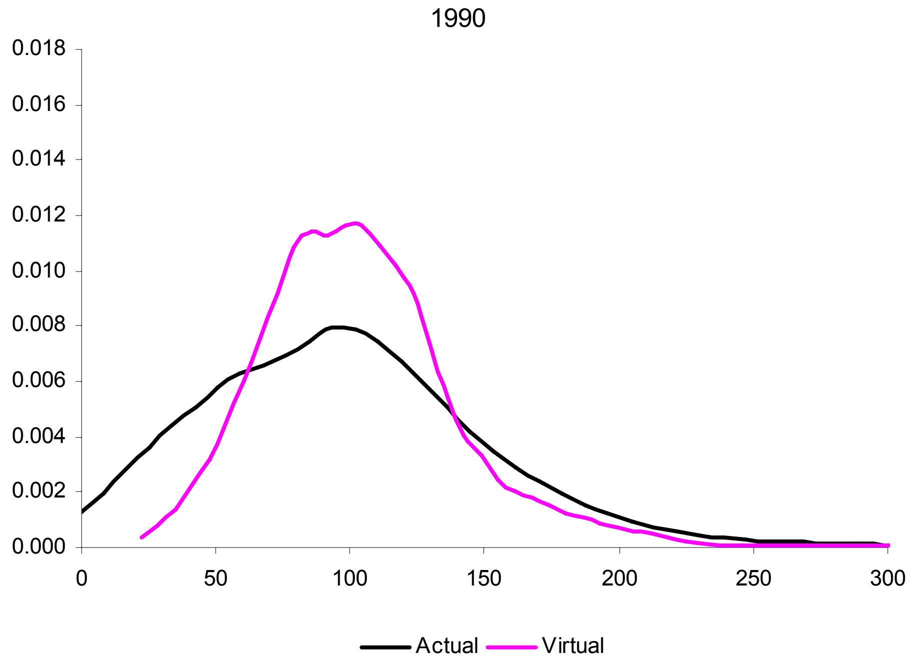
Limousin (FR63)
Rhône-Alpes (FR71)
Auvergne (FR72)
Languedoc-Roussillon (FR81)
Prov.-Alpes-Côte d'Azur (FR82)
Corse (FR83)
Ireland (IE)
Piemonte (ITC1)
Valle d'Aosta (ITC2)
Liguria (ITC3)
Lombardia (ITC4)
Bolzano-Bozen (ITD1)
Trento (ITD2)
Veneto (ITD3)
Friuli-Venezia Giulia (ITD4)
Emilia-Romagna (ITD5)
Toscana (ITE1)
Umbria (ITE2)
Marche (ITE3)
Lazio (ITE4)
Abruzzo (ITF1)
Molise (ITF2)
Campania (ITF3)
Puglia (ITF4)
Basilicata (ITF5)
Calabria (ITF6)
Sicilia (ITG1)
Sardegna (ITG2)
Luxembourg (LU)
Noord-Nederland (NL1)
Oost-Nederland (NL2)
West-Nederland (NL3)
Zuid-Nederland (NL4)
Continente (PT1)
Yorkshire and The Humber (UKE)
East Midlands (UKF)
West Midlands (UKG)
South West (UKK)
Wales (UKL)
Scotland (UKM)
Northern Ireland (UKN)

Appendix 3

Figure 6: Effect of the economic development level on the regional distribution of agricultural productivity.



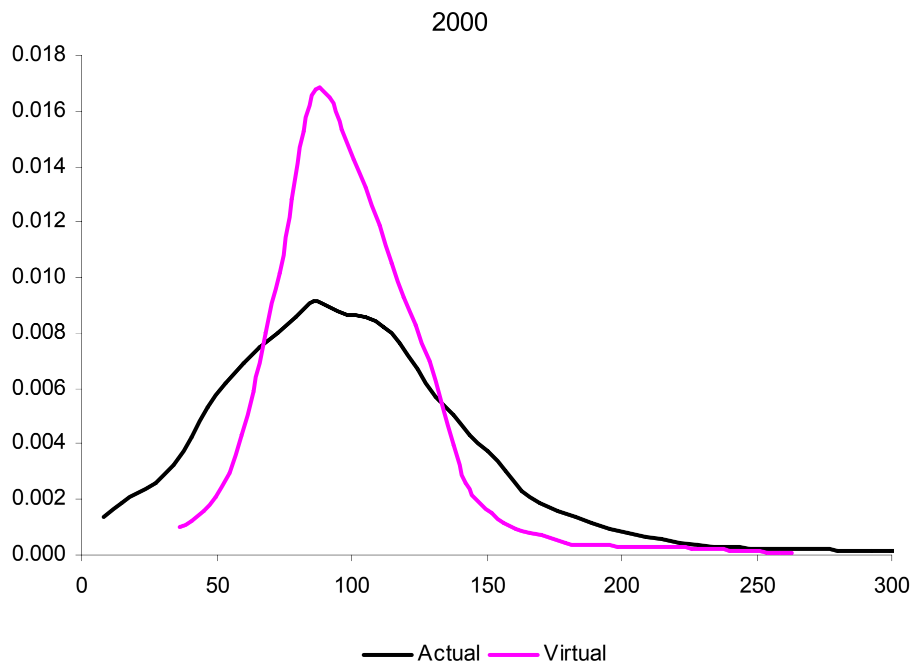
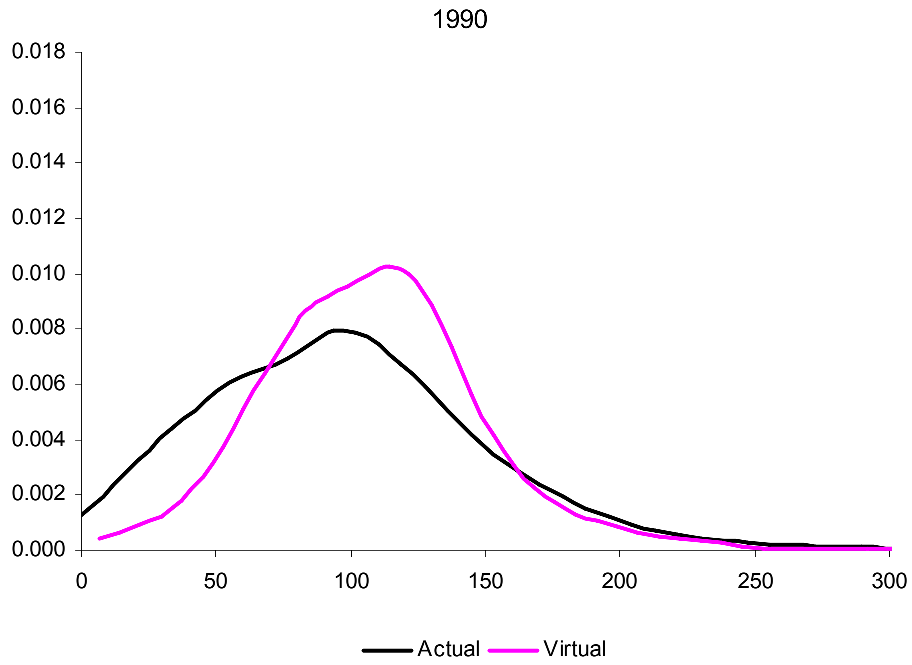


Figure 7: Effect of owner characteristics on the regional distribution of agricultural productivity.



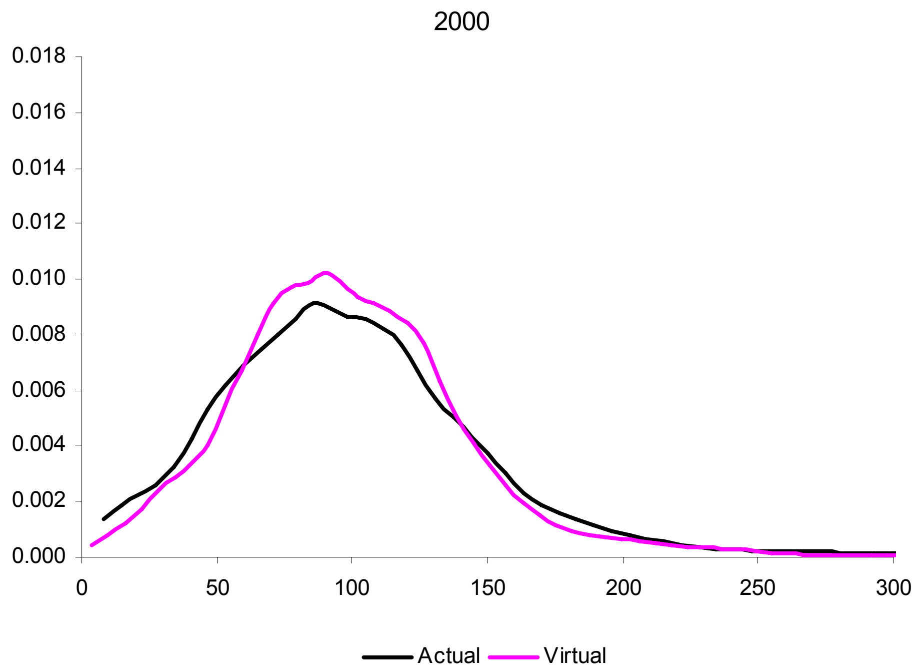
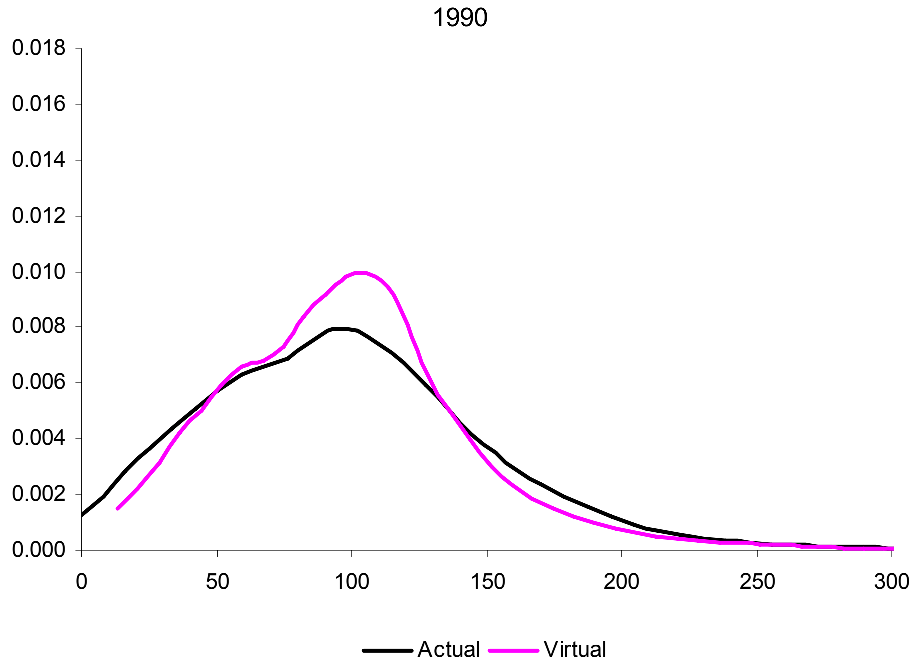


Figure 8: Effect of farm characteristics on the regional distribution of agricultural productivity.



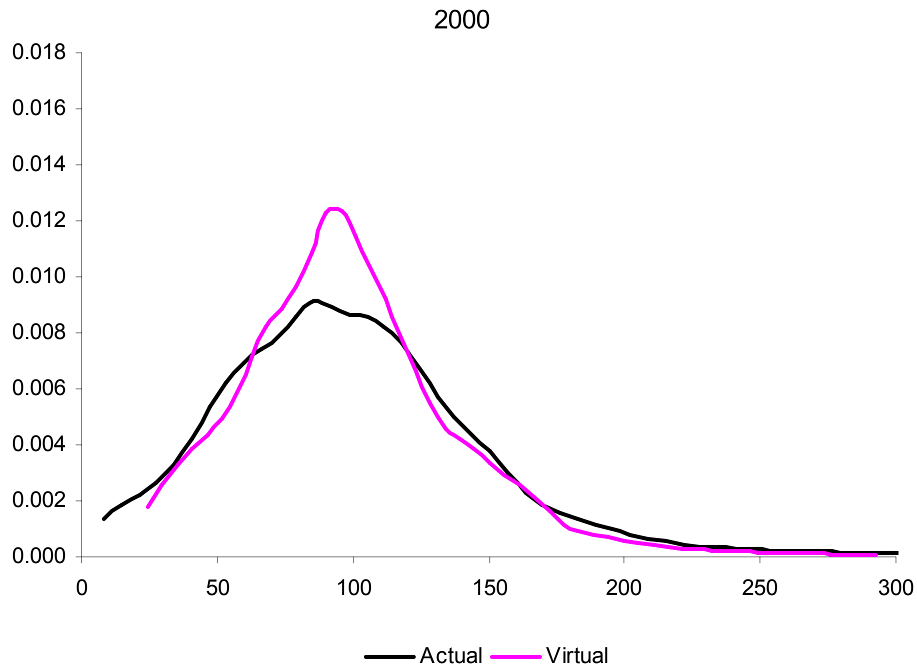
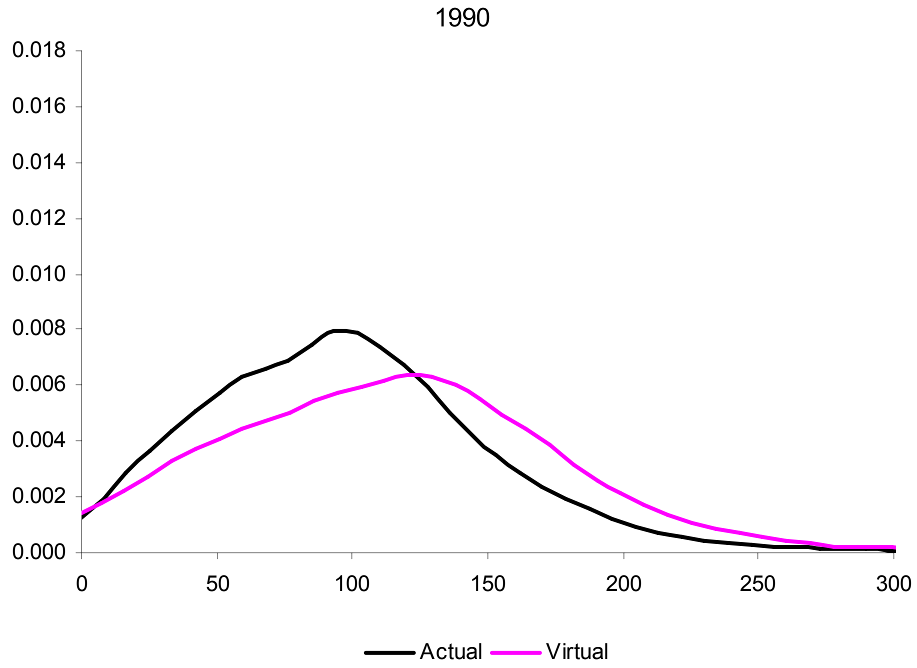
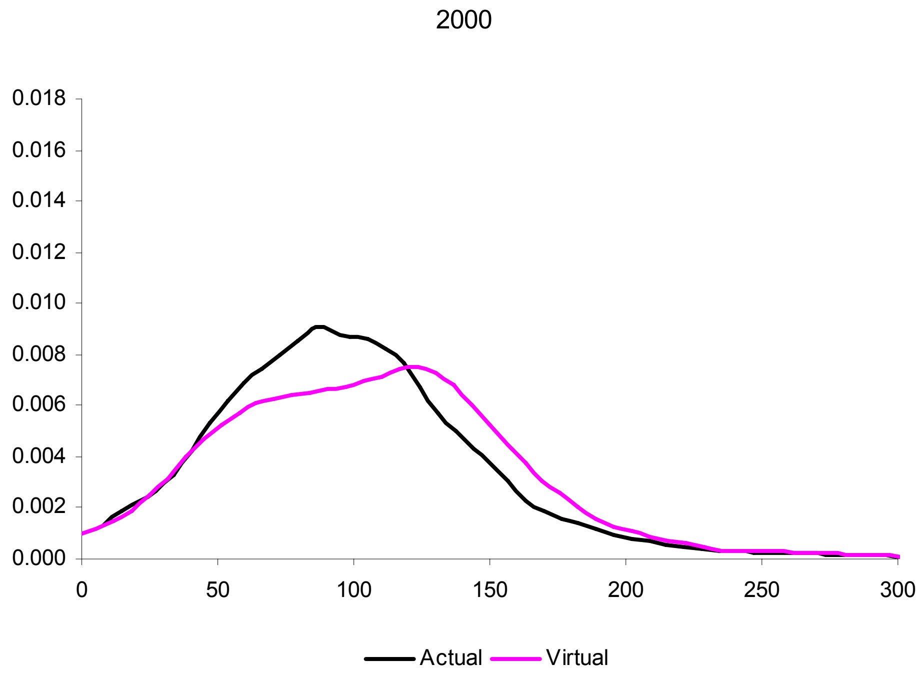


Figure 9: Effect of productive specialization on the regional distribution of agricultural productivity.





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