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Total factor productivity and its components for sheep and goat farms in 37 Southern European regions (2004-2012)

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ABSTRACT: The decline of Southern Europe's traditional sheep- and goat-farming systems creates a need for studies on the economic determinants that underlie their production processes. Using data from the FADN, we built a panel of 37 regions from 5 countries over an 8-year period (2004–2012). A Cobb-Douglas was specified and a stochastic frontier production was estimated. Total Factor Productivity (TFP) and its components were calculated. The farms have had sustained, positive development of TFP since 2008, with a significant correlation with the labour factor of production. We detected moderate technical progress change, which was accompanied by decreasing efficiency.

KEYWORDS: Europe, Regional analysis, sheep and goats, Total Factor Productivity.

Productividad total de los factores y sus componentes para explotaciones de ovinos y caprinos en 37 regiones del sur de Europa (2004-2012)

RESUMEN: El declive del ovino y caprino del sur de Europa determina la necesidad de estudios sobre su proceso productivo. Con los datos de la FADN se ha elaborado un panel de 37 regiones de 5 países para 2004-2012. A partir de una función Cobb-Douglas, se ha estimado una frontera de producción estocástica; calculando la evolución de la Productividad Total de los Factores (TFP) y sus componentes. Las explotaciones analizadas presentan una evolución sostenida y positiva de la TFP desde 2008 y una correlación con el factor trabajo. Existe un mínimo y creciente progreso técnico y una eficiencia decreciente.

PALABRAS CLAVE: Europa, Análisis regional, ovino y caprino, Productividad Total de los Factores.

JEL classification/Clasificación JEL: Q12, C51.

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1. Introduction and objective

The broad range of family farming operations and the complexity of these families' livelihoods mean that recommendations based on a single template are unsuitable. To support family farms, each country and region must provide the solutions that best suit the needs of family farmers and the local context and that utilise the capabilities and strengths of family farmers (FAO, 2015).

This introduction focuses on two essential aspects: The contribution of agriculture to economic growth and the territorial framework in which a specific sector evolves.

Sectoral growth is a matter of great interest in the economic literature. Advances in sectoral productivity lead to economic growth and well-being within a society. Regions that form a nation depend on specific geographical divisions that have arisen over the country's historical evolution. Regions maintain their own identity with specific factor endowments. Moreover, regional agricultural sectors are affected by specific policy contexts that may distort their growth. These policy contexts mainly refer to the regulations that govern agricultural holders (Aldaz and Millán, 1996). In 2001, Expósito and Rodríguez (2002) studied the evolution of the Spanish agricultural sector's productivity between 1975 and 1995. They concluded that the sector experienced modest growth in terms of productivity, which was constrained by Spain's entry into the European Economic Community during a period of profound CAP reform.

The relationship between efficiency and productivity is key for the survival of rural economies. Regional agricultural sectors comprise a wide variety of activities with widely varying functions of production and methods that differ greatly across productive orientations and regions.

The theoretical basis for this paper is rooted in the seminal work of Schultz (Schultz, 1964; Schultz, 1965), which suggests that increases in productivity in the agricultural sector arise from three sources: (i) the contribution of new techniques from biology, chemistry and mechanics; (ii) the availability of new factors of production; and (iii) technical change in agriculture and training. Schultz also highlighted the importance of public and private agricultural research, as well as the influence of effective incentives for farmers to adopt agricultural innovations. Johnson (1997) underlined the role of agriculture in growth and established that improvements in agricultural productivity result from factor substitution in the frontier production function.

Agricultural productivity has been analysed from supranational, national, regional and sectoral perspectives. Ezcurra *et al.* (2011) examined 99 European regions at the NUTS 2 level and observed the complexity of the spatial distribution of agricultural productivity and its evolution. In general, agriculture in the Northern European Union performs better than in Southern regions, with a generally positive relationship between productivity and economic development, investment per worker and the size of the farming operations. Most studies have focused on the beef sector. For example, through their analysis of German dairy farms, Sauer and Latacz-Lohmann (2015) identified the need for trained human capital to address structural challenges in the sector.

Fewer studies have addressed sheep- and goat-livestock activities. In sheep and goat farming, traditional systems have gradually disappeared, especially in the Mediterranean Basin. This process may relate to the declining rural population and unfavourable regulations on land use (El Aich *et al*., 1995). Transhumant pastoral systems have been disappearing in Europe for the past 30 years. Meanwhile, milk production systems have slowly intensified, with steady increases in farms' capitalisation levels, especially in areas with favourable agricultural and social characteristics. This study fills the gap in the literature regarding the analysis of productivity in sheep and goat farms. Our objective is *to estimate Total Factor Productivity (TFP) and its components for small ruminant (sheep and goat) farming operations in 37 regions in Southern Europe by estimating a stochastic production frontier for the period 2004 to 2012.*

2. Method

The stochastic frontier model estimates a production frontier function using econometric techniques. It requires a functional form to represent technology and incorporates a composite error. The distance to the frontier allows efficiency indices to be calculated. Preliminary versions of these models are discussed in Aigner *et al.* (1977) and Meeusen and Van Den Broeck (1977):

$$y_{it} = f\ (x_{it}, \beta_{it}) + \varepsilon_i \quad i = 1......n;\ t = 1......t \qquad [1]$$

where Y_{it} is the output of the i^{th} unit at time t, X_{it} is a vector of inputs, β is the vector of unknown parameters to be estimated and ε_i is the error term, which is composed of two independent elements, v_i and u_i, such that $\varepsilon_i = v_i - u_i$.

The term v_i –independent and identically distributed (iid) and distributed as $N(0, \sigma^2)$– is a symmetric perturbation that reflects random variations in production due to factors such as random errors and errors in data observation or measurement. The term u_i is asymmetric and reflects technical inefficiency of the observations. It is assumed that u_i is distributed independently of v_i.

The composite error term in Equation 1, which is estimated together with the baseline model, has two modelling alternatives discussed in Battese and Coelli (1992) and Battese and Coelli (1995). Battese and Coelli (1992) defined the term u_{it} as an exponential function[1] of the technical inefficiency effects of the last period in the panel data. It is extremely useful to examine their change over time. Accordingly, u_{it} are random non-negative iid variables that register technical inefficiency in production. They are distributed according to a normal truncated distribution $N(\mu, \sigma_u^2)$, where η is an unknown parameter to be estimated. If η is positive the model shows

[1] There is no consensus on the assumed distribution of the u_{it} term. The distributions proposed for the inefficiency component include the semi-normal distribution described by Aigner *et al.* (1977), the exponential distribution used by Meuseen and Van Den Broeck (1977), the truncated normal distribution introduced by Stevenson (1980) and Greene's normal gamma distribution (Greene, 1990).

that inefficiency is decreasing over time. The alternative is that inefficiency is increasing. This specification of the error term is appropriate when t is not particularly large (see Coelli and Rao, 2005):

$$u_{it} = u_i \{\exp[-\eta (t-T)]\} \quad [2]$$

Battese and Coelli (1995) proposed an alternative model in which the term u_{it} is a non-negative random variable associated with technical inefficiency in production obtained from a normal distribution truncated at zero, with a mean $Z_{it}\delta$ and a variance σ^2, where Z_{it} is a (1 x m) vector of explanatory variables associated with technical inefficiency over time and δ is an (m x 1) vector of coefficients to be estimated. Hence, the technical inefficiency u_{it} can be expressed as:

$$u_{it} = z_{it}\,\delta + w_{it} \quad [3]$$

The model proposed by Battese and Coelli (1995) [3] presents two problems: the selection of variables in the inefficiency equation and the need for a longer time frame. Given that t = 8 for our panel, we used the framework proposed by Battese and Coelli (1992).

Evolution of TFP and its components was calculated from the results obtained for the frontier function. This is defined as the ratio between the production and the cost of factors of production (Fried *et al*., 2008), through which the growth rate is determined as the difference between the rate of growth in the value of production and the rate of growth in the value of inputs (Loaiza and Franco, 2013).

In the case of a Cobb-Douglas function, Álvarez and Orea (2003) suggested that TFP trends can be decomposed into three components: Technical Progress Change (TP), Scale Efficiency Change and Technical Efficiency Change. In the following equations, the dot over the variable indicates growth rate:

$$T\dot{F}P = TP + (e-1) \sum_{j=1}^{n} \frac{e_j}{e} \dot{x}_j + \dot{E} \quad [4]$$

where TP is represented by the derivative of the function with respect to time:

$$TP \approx \delta_t + \delta_{tt} t \quad [5]$$

Note that if TP = 0, technology does not contribute to productivity gains.

The second term reflects scale efficiency change, and it is denoted by the following expression:

$$(e-1)\sum_{j=1}^{n}\frac{e_j}{e}\dot{x}_j \approx (\hat{\beta}-1).\sum_{j=1}^{n}\frac{\hat{\beta}_j}{\hat{\beta}}(\ln x_{ijt}-\ln x_{ijt-1})\,; \qquad \beta=\sum_j \hat{\beta}_j \quad [6]$$

where

$$e=\sum_{j=1}^{n} e_j \;\Rightarrow\; \sum_{j}^{n}\frac{e_j}{e}=1 \quad [7]$$

Scale Efficiency Change in production reflects the returns to scale and growth rates of the factors. In the case of constant returns to scale, elasticity is equal to unity ($e = 1$), so the second term is annulled.

The third term, Technical Efficiency Change, is defined as follows:

$$\dot{E} = \ln E_{it} - \ln E_{it-1} = -(\hat{u}_{it} - \hat{u}_{it-1}) \quad [8]$$

$\dot{E} = 0$ indicates that inefficiency has no impact on productivity gains.

A methodological review of the evolution of TFP and its breakdown in translog functions can be found in Araujo and Feitosa (2014), Kumbhakar *et al.* (2000) and Kumbhakar and Lovell (2003).

3. Empirical analysis

The data set consisted of a panel of 37 European regions for the period 2004 to 2012, using information taken from the Farm Accountancy Data Network (FADN) (European Commission, 2015), which provides data on the income and economic activities of European farms. The holdings selected for this study were located in Southern European regions where comparable data were available. The countries studied (Map 1) were the following: Greece (4 regions), Spain (10 regions), France (9 regions), Italy (11 regions) and Portugal (3 regions).

The variables used to conduct the microeconomic analysis of the farms were[2], in the first place, total production (Y) of agriculture, livestock and other products (€). Production depends on factors of production, which in a standard microeconomic framework are land, labour and capital. Land was ruled out as a factor of production because of vast disparities in land availability across the studied area according to the geographical characteristics of the location of the farms in different countries.

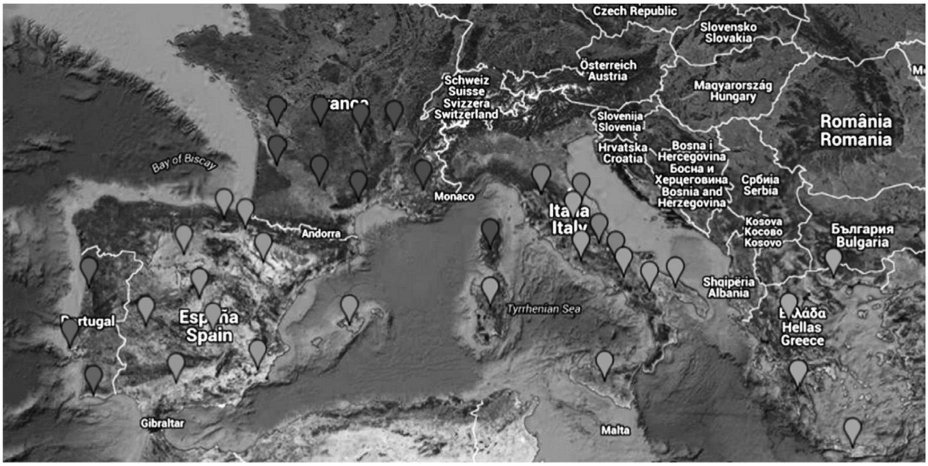
Thus, the factors of production employed in the analysis were labour and capital. Labour (L) was calculated from data on the average hourly wage in the sector (available in national statistical series) and from total hours of labour, as reported in the FADN data (€). Capital has two components in livestock farms: the fixed assets (K)

[2] A complete definition can be found at: http://ec.europa.eu/agriculture/rica/definitions_en.cfm.

available to the farm, measured in €, and the biological capital (G), which is defined as the total number of animals measured as units of cattle in the surveyed farms.

MAP 1

Geographical location of the regions



Source: Own elaboration based on FDAN data.

To standardise the monetary series over time, the monetary series were deflated using the harmonised index of consumer prices (HICP)[3] for each country. Summary statistics for the variables used in the analysis are given in Appendix 1. Lastly, the variables were transformed into logarithms. The software used was FRONTIER v 4.1[4].

After carrying out the corresponding tests[5], the production frontier function was estimated as a Cobb-Douglas function. The specification for the 37 sheep and goat regions in the five EU countries took the following form:

$$\text{Ln } y_{it} = \alpha_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_G \ln G_{it} + \delta_t t + 0.5\, \delta_{tt} t^2 + D_i\alpha_i + (v_{it}-u_{it}) \quad [9]$$

where:

Y_{it} = production of farm i during period t.

L_{it} = labour of farm i during period t.

3 http://ec.europa.eu/eurostat/web/hicp/statistics-illustrated.

4 http://www.uq.edu.au/economics/cepa/frontier.php.

5 See Table 2 and comments.

K_{it} = fixed assets of farm i during period t.

G_{it} = biological capital (units of cattle) of farm i during period t.

t = linear trend.

t^2 = quadratic trend.

α_i = fixed effects that capture heterogeneities not observed by country.

Equation 9 was estimated by maximum likelihood. The results are shown in Table 1.

TABLE 1

Estimation results

Variable	Coefficient	t-Student
Production function (Equation 9)		
$\ln L_{it}$ (β_L)	0.379	5.017^{***}
$\ln K_{it}$ (β_K)	0.186	4.598^{***}
$\ln G_{it}$ (β_G)	0.307	5.124^{***}
t (δ_t)	0.010	0.681
t^2 (δ_{tt})	0.001	0.897
D_1 (α_1)	0.826	8.379^{***}
D_2 (α_2)	1.184	12.488^{***}
D_3 (α_3)	1.257	11.546^{***}
D_4 (α_4)	1.229	11.451^{***}
Constant (α_0)	3.702	5.501^{***}
Inefficiency		
η	-0.055	-6.251^{***}
μ	0.686	5.721^{***}
σ^2	0.132	5.887^{***}
$\gamma = \sigma^2_u/(\sigma^2_v+\sigma^2_u)$	0.894	41.104^{***}
Log L	162.083	
LR test	209.402	

Note: ***Significant ($p < 0.01$).
Source: Own elaboration.

The signs obtained for the parameters related to the factors of production were positive and significant at $p < 0.01$. The function had diminishing returns[6].

A noteworthy result was the low value of the coefficient associated with K, which would appear to indicate a certain degree of overcapitalisation of small ruminant farms. Therefore, an increase in this factor might lead to inefficiency.

Given the limited number of years for the panel, Technical Progress Change was limited, a finding confirmed by the estimated trend variable parameters.

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6 The sum of the coefficients assigned to the factors of production was 0.872 (< 1).

Regarding the parameters associated with inefficiency, the negative sign for the parameter η indicated that technical inefficiency increased over time. The parameter γ was statistically significant at $p < 0.01$, with a value of 0.894. The composite error term included virtually all inefficiency. The calculation of variances confirmed this finding: $\sigma^2_u = 0.110$ and $\sigma^2_v = 0.022$.

The selection of the functional form and the composite error term entailed subjecting the model to a series of tests, all of which included the likelihood ratio test[7]. The results are shown in Table 2.

TABLE 2

Test results

Test	Null hypothesis	λ value	Critical value (95 %)	Decision
1	H_0: $\beta_{LL} = \beta_{KK} = \beta_{GG} = \beta_{LK} = \beta_{LG} = \beta_{KG} = 0$ (Cobb-Douglas)	5.258	11.91	No reject H_0
2	H_0:$\gamma = 0$ (Stochastic inefficiency)	209.402	2.706	Reject H_0
3	H_0:$\eta = 0$ (Invariant inefficiency)	16.686	2.706	Reject H_0
4	H_0:$\mu = 0$ (Semi-normal inefficiency effect)	11.926	2.706	Reject H_0
5	H_0: $\delta_t = \delta_{tt} = 0$ (No TPC)	42.508	5.138	Reject H_0
6	H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$ (No fixed effects)	41.588	8.761	Reject H_0

Source: Own elaboration.

The first test explored the null hypothesis of a Cobb-Douglas functional form compared with a translog. The values obtained were consistent with H_0, indicating that a Cobb-Douglas specification is appropriate to represent the panel.

The second test assessed whether sheep and goat holdings in Mediterranean Europe operated on the frontier or whether the function could be estimated by least squares. This hypothesis was rejected, thereby confirming the structure of the composite error in the model.

For the tests related to the inefficiency term, we evaluated whether inefficiency was time invariant and then whether the effects of inefficiency had a semi-normal distribution. Both hypotheses were rejected, indicating that technical inefficiency was increasing over time and that the effects of inefficiency had a truncated normal distribution.

To determine the existence of Technical Progress Change, the model was estimated without the trend variables, and H_0 was rejected, indicating that Technical Progress Change was present in the model, albeit minimally (test 5).

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[7] $\lambda = -2\{\log.f.likelihood(H_0)-\log.f.likelihood(H_1)\}$. The Kodde and Palm table (1986) was used to compare critical values of the results, given the degrees of freedom.

Lastly, to test for the presence of fixed effects in the model captured by the dummy variable (test 6), the model was again estimated without these variables. In this case, H_0 was rejected, confirming the existence of fixed effects in the model.

4. Main findings

The decomposition of the TFP change by country for the period 2004 to 2012 is shown in Table 3. The individual results by region can be found in Appendix 2.

TABLE 3

TFP evolution by country (2004-2012)

	Total factor productivity	Scale change	Technical progress change	Technical efficiency change
Greece	0.001	0.001	0.016	-0.017
Spain	-0.002	-0.001	0.016	-0.017
France	0.003	0.001	0.016	-0.014
Italy	-0.001	0.002	0.016	-0.019
Portugal	0.005	0.001	0.016	-0.012
Average	0.001	0.001	0.016	-0.016

Source: Own elaboration.

TFP change was positive in Portugal, France and Greece, with the highest value in Portugal and lowest in Greece. In contrast, Spain and Italy had negative values. The complexity of studies on sheep and goat farming and the vast differences in target periods, breeds, locations and methodologies make it difficult to compare findings and draw general conclusions.

Using DEA methodology, Coelli and Rao (2005) calculated the evolution of the agricultural TFP for 93 countries. Their results indicate the same order of countries as the order observed for our sample. Given that nonparametric analysis such as DEA tends to overvalue TFP results (Trillo, 2002) and that Coelli and Rao (2005) estimated values for the overall agricultural sector, our findings seem consistent with the reality in the sector.

Haniotis (2013) analysed trends in agricultural TFP in the EU27 and obtained negative values for Italy and Spain, values very close to 0 for Greece and France, and clearly positive values for Portugal. These findings were attributed to the decreasing productivity of capital in the agricultural sector in the EU15. Again, Haniotis reported the results for the overall agricultural sector, whereas the present study focused on a particular type of livestock.

Regarding Scale Efficiency Change, the parameters of the variables indicated diminishing returns. For Greece, France, Italy and Portugal, increases in the factors of labour and capital caused a very weak increase in final production. In Spain, any increase in factor endowment contributed negatively to TFP change.

Technical Progress Change has a common value of 0.016 for all countries, which is due to the functional form adopted. This value indicates that Technical Progress Change plays a limited role in sheep and goat farming in Southern Europe. This finding validates the results of the estimation (Table 1) and tests (Table 2), and it represents a compensating element for the evolution of TFP.

The average change in technical efficiency, as a third element of the evolution of TFP, was negative and very similar across regions. Negative Technical Efficiency Change is therefore compatible with positive Technical Progress Change. Araujo and Feitosa (2014) did not report positive technical change in the reference period, perhaps because of problems in adopting modern techniques in traditional sectors such as the sector analysed in this paper.

TABLE 4

Evolution of TFP over time (2004–2012)

Years	**Total Factor Productivity**	**Scale Efficiency Change**	**Technical Progress Change**	**Technical Efficiency Change**
2004-05	-0.004	-0.001	0.012	-0.015
2005-06	-0.005	-0.002	0.013	-0.016
2006-07	0.004	0.006	0.014	-0.016
2007-08	-0.005	-0.004	0.016	-0.017
2008-09	0.001	0.001	0.017	-0.017
2009-10	0.004	0.003	0.018	-0.017
2010-11	0.003	0.001	0.019	-0.017
2011-12	0.003	0.000	0.020	-0.018
Average	0.000	0.001	0.016	-0.017

Source: Own elaboration.

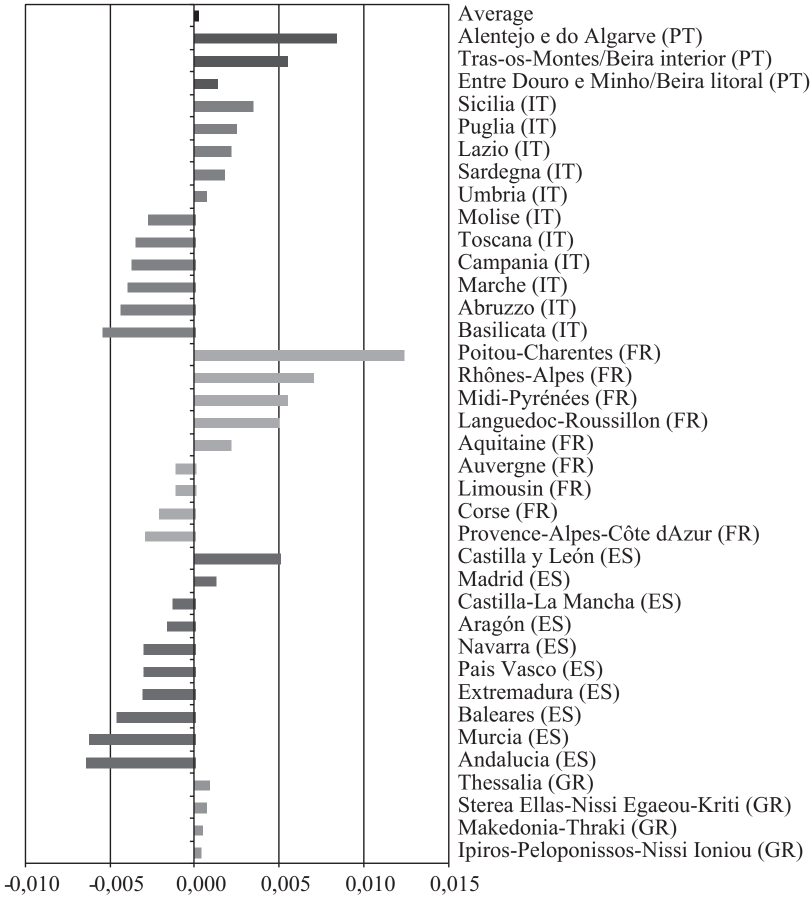
Table 4 shows the evolution of TFP and its components over time. Negative changes in TFP may seem surprising from the perspective of standard microeconomic analysis, but they are endorsed by the findings of Fuglie (2010), who reported negative values of this variable for the period 2000 to 2007 in Eastern Europe (-0.12) and Australia and New Zealand (-0.53), where sheep are important. The positive and increasing values for Technical Progress Change contribute to bridging the gap between TFP and Scale Efficiency Change. Lastly, efficiency decreased over time, a finding that had already been indicated by the sign of the η parameter (Table 1).

Together, both findings confirm the low value of the coefficient of K (Table 1). Previous studies have noted the serious impact of overcapitalisation on the productive efficiency of small ruminant farms (Hidalgo *et al*., 2011).

The regional analysis of the evolution of the TFP (Figure 1) revealed that 19 of the 37 regions had positive performance that surpassed the mean for the set.

FIGURE 1

TFP regional evolution (2004–2012)



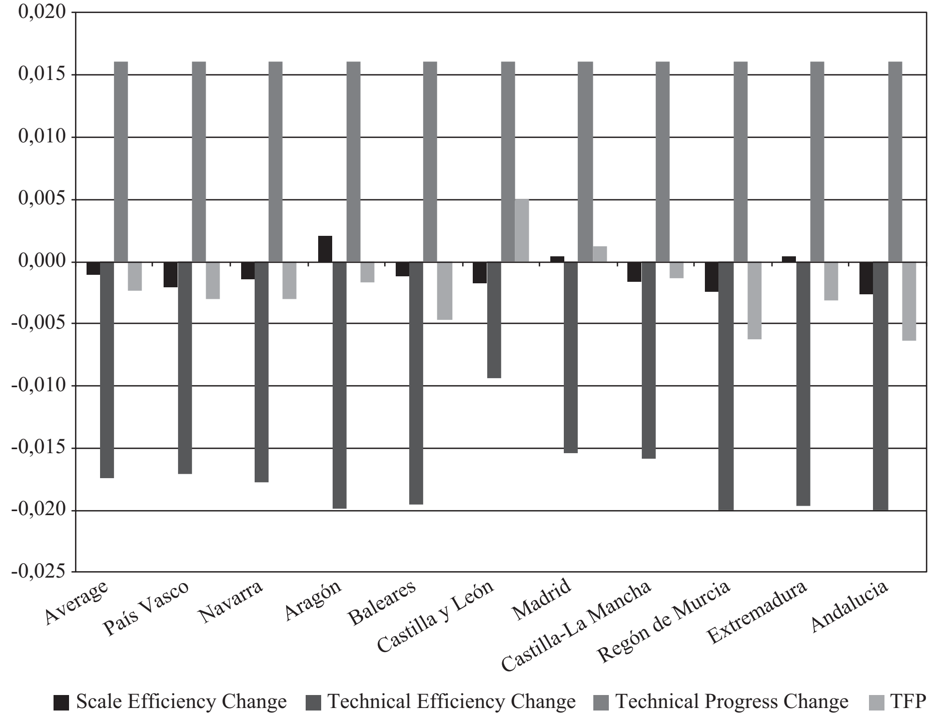
France: FR; Portugal: PT; Greece: GR; Spain: SP; Italy: IT.
Source: Own elaboration.

Our findings for Spanish regions are consistent with those reported by Aldaz and Millán (1996), who used comparative analysis of indices obtained from DEA methodology to show that Spanish regions with a TFP below the mean share a significant weight of livestock in final agricultural production. Only Madrid and Castilla y León had higher Technical Progress Change than the other Spanish regions and smaller decreases in the values for Technical Efficiency Change.

Figures 2, 3, 4, 5 and 6 show the evolution of TFP and its components for the regions under study. In Spain, the regions that reared the most productive breeds, whether due to genetics or more intensive farming methods (e.g. widespread rearing of the Assaf breed in Castilla y León or more intensive farming in Madrid), had positive TFP change (Figure 2).

FIGURE 2

Evolution of TFP and its components in Spain (2004-2012)

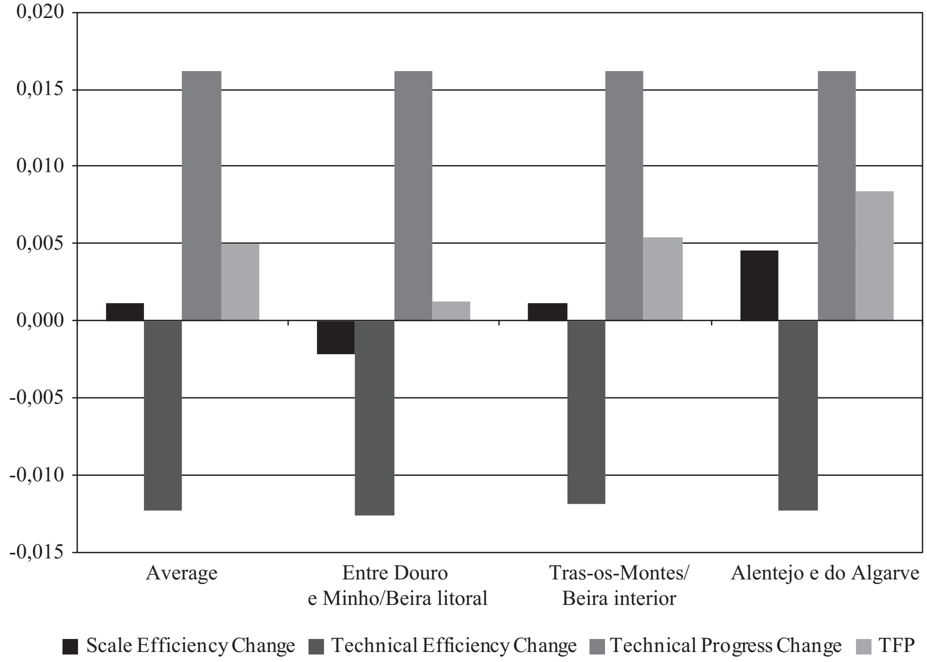


Source: Own elaboration.

The Portuguese case (Figure 3) is noteworthy because all TFP values were positive. The reason for this result may be that the number of sheep producers is decreasing while the number of animals per farm is increasing, which means that small-scale production is being replaced by larger-scale production. Portugal has a high concentration of sheep production in the Alentejo, where the size of the herd is larger than in any other region (Tiberio and Diniz, 2014).

FIGURE 3

Evolution of TFP and its components in Portugal (2004-2012)



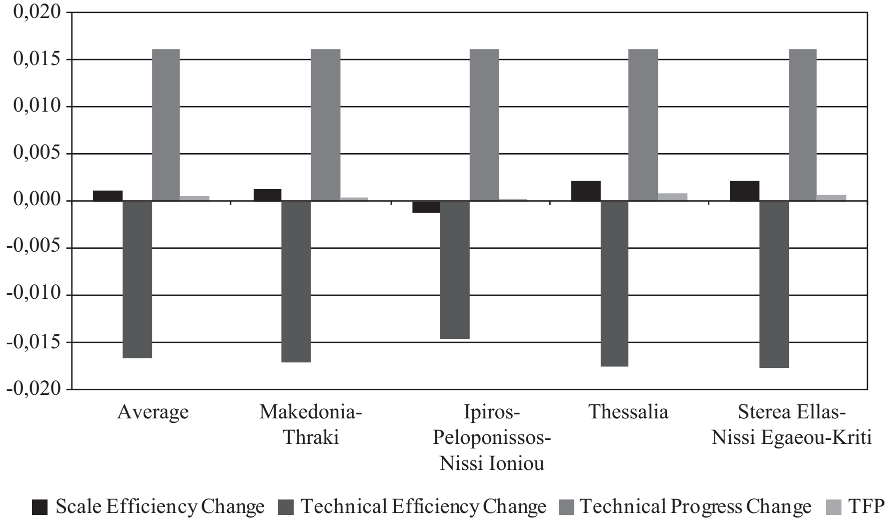
Source: Own elaboration.

In Greece (Figure 4), sheep and goat production is mostly extensive. In fact, when farm size grows, labour grows more than proportionally because holders have little interest in replacing labour with capital. The tough working conditions within these systems mean that this profession has an image of being 'socially unacceptable' (Hadjigeorgiou *et al*., 2002). Karagiannis and Tzouvelekas (2005) reported that the scale effect played a significant role in explaining TFP evolution and caused a slow-down in output of 0.35 % per annum.

In France (Figure 5), the evolution of TFP follows two trends: One negative and one positive, mainly in northern regions.

FIGURE 4

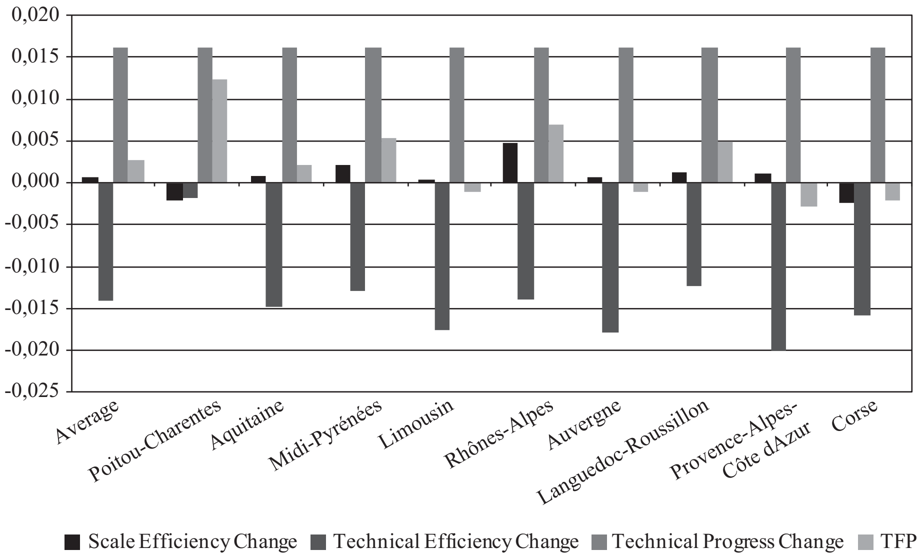
Evolution of TFP and its components in Greece (2004-2012)



Source: Own elaboration.

FIGURE 5

Evolution of TFP and its components France (2004-2012)



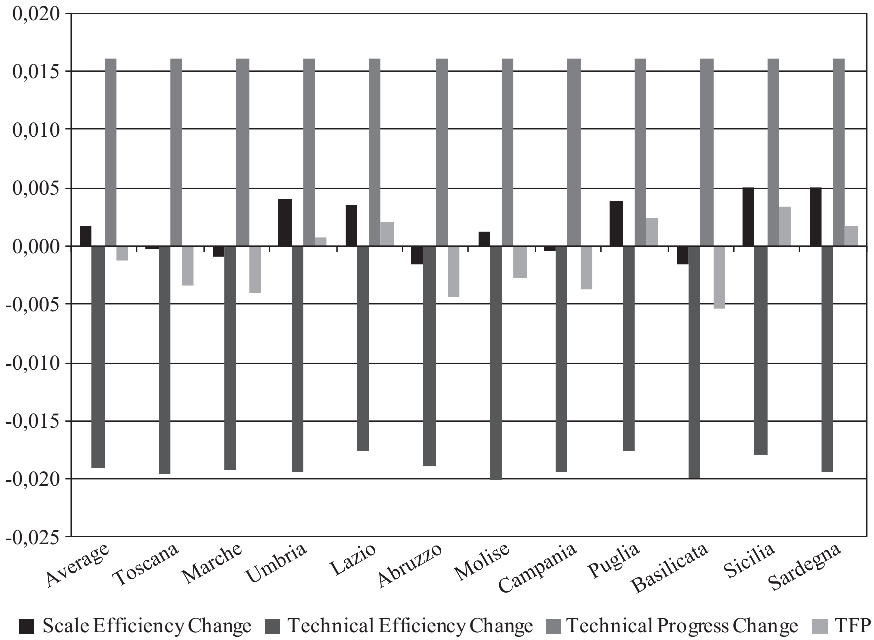
Source: Own elaboration.

The Italian case (Figure 6) is similar to the French one. Only three regions had positive TFP (Sicilia, Puglia, Lazio, Sardinia and Umbria) because of the compensating effect of economies of scale in these areas.

Given the relevance of the labour factor in this kind of activity, we explored the correlation between the variation rate of the labour factor and TFP (Table 5). Generally, there was significant negative correlation between trends in both factors, with a mean result of -0.563, reflecting an inverse trend between labour and TFP. This result confirms the initial hypothesis of a high intensity in the use of this factor in a sector with highly traditional management practices.

FIGURE 6

Evolution of TFP and its components in Italy (2004–2012)



Source: Own elaboration.

TABLE 5

Correlation coefficients between labour factor variation rate and TFP

Pais vasco (ES)	-0.930	Thessalia (GR)	-0.883
Castilla-león (ES)	-0.732	Ipiros-Peloponissos-Nissi Ioniou (GR)	-0.735
Navarra (ES)	-0.705	Makedonia-Thraki (GR)	-0.614
Murcia (ES)	-0.641	Sterea Ellas-Nissi Egaeou-Kriti (GR)	0.190
Baleares (ES)	-0.541	Lazio (IT)	-0.983
Castilla-la mancha (ES)	-0.515	Sardegna (IT)	-0.933
Andalucia (ES)	-0.436	Puglia (IT)	-0.877
Aragón (ES)	-0.356	Sicilia (IT)	-0.876
Extremadura (ES)	-0.208	Toscana (IT)	-0.866
Madrid (ES)	-0.103	Umbria (IT)	-0.523
Limousin (FR)	-0.915	Abruzzo (IT)	-0.491
Midi-pyrénées (FR)	-0.793	Basilicata (IT)	-0.458
Languedoc-Roussillon (FR)	-0.760	Molise (IT)	-0.441
Corse (FR)	-0.759	Marche (IT)	-0.170
Rhônes-alpes (FR)	-0.752	Campania (IT)	-0.126
Aquitaine (FR)	-0.546	Tras-os-montes/Beira interior (PT)	-0.797
Poitou-charentes (FR)	-0.527	Entre Douro e Minho/Beira litoral (PT)	-0.586
Auvergne (FR)	-0.335	Alentejo e do Algarve (PT)	-0.282
Provence-alpes-côte d'azur (FR)	0.156	**Average**	**-0.563**

France: FR; Portugal: PT; Greece: GR; Spain: SP; Italy: IT.
Source: Own elaboration.

5. Conclusions

Drawing upon FADN data, we estimated TFP and its components using a stochastic production frontier function for sheep and goat farms in 37 regions of five Southern European countries for the period 2004 to 2012. Based on likelihood ratio tests, the translog specification was not accepted, nor was the hypothesis of no Technical Progress Change. A Cobb-Douglas frontier function was estimated with moderate Technical Progress Change.

TFP evolved negatively in two of the five countries under study. Such cases were characterised by a correlation between the evolution of returns to scale of labour and TFP. Sheep and goat farming still depends strongly on the regional context and still provides a livelihood for many families in Southern Europe. The traditional ways of life associated with these forms of production give rise to conservative farming approaches where limited Technical Progress Change is linked to gradual intensification of farming due to two factors: (i) overinvestment in machinery and facilities, which leads to overcapacity and a consequent reduction in technical efficiency and (ii) the use of more productive biological capital, which generates positive TFP levels.

The survival of small livestock holdings is important in rural areas. The solution is to design targeted policies that are able to diversify activities and reduce farms' structural problems through techniques that allow increasing returns to scale, more efficient use of factors and technical modernisation.

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Appendix 1: Description of the sample data (N=333)

	Y	L	G	K
Mean	48,717.0	3,181.9	37.5	243,558.7
Std Dev.	5,152.6	198.2	2.5	40,991.9
Maximun	141,892.7	8,205.2	89.2	901,932.9
Minimun	8,114.8	1,802.9	7.1	36,994.4

Source: Own elaboration.

Country	Region	Mean Y	Mean L	Mean G	Mean K
Greece	Makedonia-Thraki	34,411.5	4,425.0	33.3	77,608.2
Greece	Ipiros-Peloponissos-Nissi Ioniou	32,153.5	3,583.2	26.2	60,683.2
Greece	Thessalia	36,352.4	5,647.5	33.0	84,652.3
Greece	Sterea Ellas-Nissi Egaeou-Kriti	34,442.9	4,115.7	37.6	92,385.0
Spain	Pais Vasco	44,938.3	3,292.2	22.1	164,091.6
Spain	Navarra	51,835.1	2,481.7	46.0	289,885.3
Spain	Aragón	44,560.2	2,530.4	79.4	252,216.0
Spain	Baleares	20,681.7	2,087.6	26.8	229,353.1
Spain	Castilla-León	85,111.1	3,123.5	45.4	326,134.7
Spain	Madrid	70,416.3	4,009.4	38.0	231,367.1
Spain	Castilla-La Mancha	76,591.3	3,931.5	59.0	270,720.5
Spain	Murcia	41,194.2	3,104.8	53.7	218,591.8
Spain	Extremadura	45,979.1	3,239.6	42.9	279,626.0
Spain	Andalucia	40,981.2	2,884.2	42.1	333,227.8
France	Poitou-Charentes	115,910.3	2,737.1	62.0	284,422.9
France	Aquitaine	56,989.7	2,429.3	31.7	220,787.7
France	Midi-Pyrénées	82,285.2	2,755.2	58.3	283,521.1
France	Limousin	63,386.7	2,486.1	70.8	255,520.7
France	Rhônes-Alpes	62,453.6	2,465.3	41.0	208,559.4
France	Auvergne	62,524.4	2,619.1	68.8	251,121.2
France	Languedoc-Roussillon	71,491.8	2,501.2	42.6	256,259.0
France	Provence-Alpes-Côte dAzur	42,155.9	2,353.3	83.3	267,911.4
Italy	Corse	49,043.6	2,156.3	33.1	157,383.0
Italy	Toscana	50,966.5	3,999.7	25.9	488,826.9
Italy	Marche	48,409.8	3,374.6	31.4	376,256.6

Country	Region	Mean Y	Mean L	Mean G	Mean K
Italy	Umbria	37,694.6	3,319.1	17.8	275,000.2
Italy	Lazio	52,103.0	2,989.6	27.3	338,184.4
Italy	Abruzzo	44,401.6	3,412.8	24.7	219,238.8
Italy	Molise	26,001.4	2,896.2	17.9	172,859.5
Italy	Campania	32,249.9	2,887.7	15.4	194,980.9
Italy	Puglia	73,567.6	5,770.0	25.7	570,062.0
Italy	Basilicata	32,051.4	3,145.4	16.8	274,747.7
Italy	Sicilia	49,179.8	3,220.0	22.4	308,708.1
Italy	Sardegna	52,203.5	3,402.9	35.7	445,096.1
Portugal	Entre Douro e Minho/Beira litoral	10,673.5	2,899.8	11.8	52,896.5
Portugal	Tras-os-Montes/Beira interior	11,911.5	2,802.9	14.7	57,897.6
Portugal	Alentejo e do Algarve	15,225.1	2,650.2	22.1	140,888.8

Source: Own elaboration.

Country	Region	Std. dev. Y	Std. dev. L	Std. dev. G	Std. dev. K
Greece	Makedonia-Thraki	2,880.7	213.2	1.1	2,499.2
Greece	Ipiros-Peloponissos-Nissi Ioniou	2,277.8	144.9	1.8	4,491.7
Greece	Thessalia	1,484.6	619.8	1.9	8,438.9
Greece	Sterea Ellas-Nissi Egaeou-Kriti	4,306.5	237.0	3.1	10,566.4
Spain	Pais Vasco	15,903.9	591.9	5.6	35,833.5
Spain	Navarra	10,367.8	110.0	4.8	82,070.5
Spain	Aragón	5,357.7	200.1	2.9	45,861.1
Spain	Baleares	4,319.1	160.5	3.0	57,136.3
Spain	Castilla-León	8,337.8	199.9	5.2	77,215.9
Spain	Madrid	21,756.4	524.4	2.1	108,596.1
Spain	Castilla-La Mancha	7,465.7	368.0	5.3	59,941.2
Spain	Murcia	5,863.4	341.0	12.9	49,085.9
Spain	Extremadura	8,156.2	215.4	3.4	84,702.3
Spain	Andalucia	6,200.0	173.3	3.6	37,629.5
France	Poitou-Charentes	14,445.2	221.4	3.6	37,674.9
France	Aquitaine	3,551.5	146.7	1.3	9,987.9
France	Midi-Pyrénées	6,403.5	244.2	2.3	16,179.4
France	Limousin	4,473.0	121.5	5.6	9,016.3
France	Rhônes-Alpes	5,512.2	129.2	8.8	35,888.5

Country	Region	Std. dev. Y	Std. dev. L	Std. dev. G	Std. dev. K
France	Auvergne	3,784.5	324.2	11.4	20,008.0
France	Languedoc-Roussillon	5,164.0	176.5	6.2	24,640.7
France	Provence-Alpes-Côte dAzur	3,827.2	109.0	2.6	14,911.4
Italy	Corse	4,025.4	60.0	4.3	11,793.2
Italy	Toscana	12,784.0	439.8	4.7	70,807.0
Italy	Marche	3,476.2	545.4	5.3	90,279.7
Italy	Umbria	7,257.9	493.0	3.7	29,806.5
Italy	Lazio	9,587.3	490.2	4.2	106,785.1
Italy	Abruzzo	8,307.9	412.9	4.3	57,020.5
Italy	Molise	2,988.4	251.5	3.0	19,989.5
Italy	Campania	5,480.5	400.1	2.7	29,829.7
Italy	Puglia	22,970.5	1,069.6	4.8	203,532.2
Italy	Basilicata	3,689.4	232.3	2.3	39,715.0
Italy	Sicilia	8,888.0	261.0	3.1	67,911.2
Italy	Sardegna	10,925.4	549.3	5.3	103,784.1
Portugal	Entre Douro e Minho/Beira litoral	1,334.8	274.0	2.6	8,281.4
Portugal	Tras-os-Montes/Beira interior	1,256.9	287.7	1.2	9,470.0
Portugal	Alentejo e do Algarve	2,131.5	307.1	2.8	42,577.5

Source: Own elaboration.

Appendix 2

Country	Region	Scale Efficiency Change	Technical Efficiency Change	Technical Progress Change	TFP
Greece	Makedonia-Thraki	0.0013	-0.0171	0.0161	0.0004
Greece	Ipiros-Peloponissos-Nissi Ioniou	-0.0012	-0.0146	0.0161	0.0003
Greece	Thessalia	0.0022	-0.0175	0.0161	0.0008
Greece	Sterea Ellas-Nissi Egaeou-Kriti	0.0022	-0.0176	0.0161	0.0007
Spain	Pais Vasco	-0.0020	-0.0171	0.0161	-0.0030
Spain	Navarra	-0.0014	-0.0177	0.0161	-0.0030
Spain	Aragón	0.0021	-0.0199	0.0161	-0.0016
Spain	Baleares	-0.0012	-0.0196	0.0161	-0.0046

Spain	Castilla-León	-0.0017	-0.0094	0.0161	0.0050
Spain	Madrid	0.0004	-0.0153	0.0161	0.0012
Spain	Castilla-La Mancha	-0.0016	-0.0158	0.0161	-0.0013
Spain	Murcia	-0.0024	-0.0200	0.0161	-0.0063
Spain	Extremadura	0.0004	-0.0196	0.0161	-0.0031
Spain	Andalucia	-0.0026	-0.0199	0.0161	-0.0064
France	Poitou-Charentes	-0.0020	-0.0018	0.0161	0.0123
France	Aquitaine	0.0008	-0.0148	0.0161	0.0021
France	Midi-Pyrénées	0.0022	-0.0129	0.0161	0.0054
France	Limousin	0.0004	-0.0177	0.0161	-0.0011
France	Rhônes-Alpes	0.0048	-0.0139	0.0161	0.0070
France	Auvergne	0.0006	-0.0179	0.0161	-0.0011
France	Languedoc-Roussillon	0.0012	-0.0124	0.0161	0.0050
France	Provence-Alpes-Côte d'Azur	0.0010	-0.0200	0.0161	-0.0029
Italy	Corse	-0.0024	-0.0158	0.0161	-0.0021
Italy	Toscana	-0.0001	-0.0195	0.0161	-0.0034
Italy	Marche	-0.0009	-0.0193	0.0161	-0.0040
Italy	Umbria	0.0040	-0.0195	0.0161	0.0007
Italy	Lazio	0.0036	-0.0176	0.0161	0.0021
Italy	Abruzzo	-0.0016	-0.0189	0.0161	-0.0044
Italy	Molise	0.0012	-0.0200	0.0161	-0.0027
Italy	Campania	-0.0004	-0.0195	0.0161	-0.0037
Italy	Puglia	0.0039	-0.0176	0.0161	0.0025
Italy	Basilicata	-0.0016	-0.0199	0.0161	-0.0054
Italy	Sicilia	0.0051	-0.0179	0.0161	0.0034
Italy	Sardegna	0.0050	-0.0194	0.0161	0.0017
Portugal	Entre Douro e Minho/Beira litoral	-0.0022	-0.0127	0.0161	0.0013
Portugal	Tras-os-Montes/Beira interior	0.0011	-0.0119	0.0161	0.0054
Portugal	Alentejo e do Algarve	0.0046	-0.0123	0.0161	0.0084
Portugal	Makedonia-Thraki	0.0006	-0.0166	0.0161	0.0001

Source: Own elaboration.