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Why did agricultural labour productivity not converge in Europe from 1950 to 2005?

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Abstract

This paper offers a long-term analysis of agricultural labour productivity differences in Europe using econometric techniques. The results show the crucial importance of the land/labour ratio. The continuous exit of manpower from the sector, coupled with increased use of productive factors originating in other sectors of the economy, caused the efficiency of agricultural workers to rise. The different relative importance of these processes across countries largely explains why labour productivity did not converge. In turn, institutions have apparently conditioned differences in productivity, as a direct and inverse relation is detected between membership of the EU and the Communist block and the productivity of agricultural labour.

JEL codes: N50, N54, O13, Q10

Keywords: Agricultural labour productivity, European agriculture 20th century, European economic development

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1. Introduction

In recent decades an important part of European economic history has tried to extend the analysis of the evolution of the different national cases by using comparative perspectives which include a significant number of countries[1]. This literature addresses one of the central problems of economics, the causes of and obstacles to modern economic growth, through the analysis of the rhythms and patterns of European economic development over the last two centuries.

The changes in agriculture and its influence on industrialization have occupied a central place in such literature (Grigg, 1992; Bairoch, 1999; Federico, 2005a; Lains and Pinilla, 2009a; Pinilla, 2009). This is logical when it is remembered on the one hand that the European economies were essentially agricultural prior to industrialization, and on the other hand that there has been an important theoretical debate about the role of agriculture in the processes of economic development (Lains and Pinilla, 2009b; Timmer 2009).

Historical differences in the evolution of agricultural productivity have received considerable attention (Olsson and Svensson, 2011). This issue is essential, owing to the fact that agricultural modernization and its positive contribution to economic development require a substantial increase in productivity. The most influential studies have invariably been of the period 1870-1914 (O'Brien and Prados 1992; Van Zanden 1991).

From the perspective of agricultural economics, one of the seminal contributions has been made by Hayami and Ruttan (1985). In general, attention has been concentrated on Total Factor Productivity (TFP), for highly varied time periods and very large samples of countries. Successive methodological advances include Data Envelopment Analysis (DEA) and the Stochastic Frontier Model (Coelli and Rao, 2005; Alauddin *et al*., 2005; Ogunyika and Langemeier, 2004; Ball *et al.*, 2001; Hadley, 2006, among others).

The present article offers a long-term analysis of agricultural labour productivity differences in Europe. This partial productivity measure does not fully reflect the variation in real agricultural productivity, for which Total Factor

[1]Broadberry and O'Rourke (2010) offer a recent and full synthesis of the economic history of this continent since 1700

Productivity would be most appropriate. However, agricultural labour productivity is extremely important because it gives a good approximation of production and income per worker in this sector[2]. As for shorter periods in agricultural economics, it systematically compares the evolution of European countries, using econometric techniques to provide explanations. The principal objective is to determine why the productivity of agricultural labour has not converged in Europe in the last 60 years.

This absence of convergence is surprising, as the period has witnessed the Europe-wide diffusion of technologies significantly advancing the frontiers of production possibilities. The period is particularly interesting, as it has experienced the greatest growth in agricultural productivity in the last two centuries. For the last 60 years most analyses have employed a highly heterogeneous sample of countries, comparisons between developed and developing countries and reduced time periods. The present study extends the usual time horizon and analyses almost all the countries of Europe, except for the former Soviet republics, for which homogenous data are difficult to obtain.

The results show the crucial importance for European labour productivity levels of the land/labour ratio. That is to say, factors from outside the agricultural sector itself, namely the capacity of other sectors to attract agricultural workers, have partly explained productivity differences. Also significant have been the endowment of fertilizers, machinery, irrigated land or livestock capital per worker. The article argues that the exodus of workers has contributed to increasing productivity levels and the far-reaching implementation of new production technologies. Lastly, the institutional framework also explains productivity differences. Especially in Western European countries, membership of the European Union has encouraged high levels of productivity. For Eastern European countries, relatively low productivity levels were maintained, due to the centralized planning of their economies. In addition, geographical conditions, above all aridity and a polar climate, explain productivity differences.

Section 2 below examines the evolution of agricultural productivity in Europe and analyses convergence. Section 3 presents the theoretical model

[2] An estimate of the TFP for the same European countries and time sample of this paper is presented in Martín-Retortillo and Pinilla (2012).

constructed, the econometric methodology followed and the variables employed. Section 4 discusses the results obtained, and Section 5 presents the principal conclusions.

2. The evolution of agricultural labour productivity in Europe

2.1. Agricultural labour productivity changes in Europe

Following Bairoch (1999) and using his data, three stages can be distinguished in the evolution of labour productivity in European agriculture over the last two centuries. The first, between 1800 and 1870, saw continuous but moderate growth, due to the adoption by Western European countries of innovatory techniques previously developed in Great Britain. Examples are new crop rotations, with the introduction of pulses and other fodder crops and the elimination of fallow periods, improved implements, more intensive fertilizing and new fertilizers such as guano (Allen, 1992 and 1994; Clark, 1987)[3]. The average annual growth of labour productivity was 0.93%.

The second stage was 1870-1950, in which annual growth accelerated to 1.23%. The use of chemical fertilizers, biological innovations, reaping and threshing machines, new metal instruments and concentrated feeds were all causes (Chorley 1981; Van Zanden 1991; Olmstead and Rhode 2008).

The greatest annual growth in productivity (4.73% on average) took place from the Second World War to the end of the twentieth century. This was due to the increasing use of self-propelled machinery, chemical fertilizers and pesticides, the genetic selection and hybridization of seeds, the development of intensive industrial livestock raising, improved access to agricultural credit and expanded irrigated farming in the Mediterranean countries (Grigg, 1992; Gardner, 1996; Evenson and Golling, 2003; Federico, 2005a; Josling, 2009).

To analyze this last stage more precisely, Table 1 offers the calculation made of agricultural labour productivity in Europe as a whole, and its agricultural production and principal productive factors. To obtain labour productivity, net production in dollars at international prices in 1999-2001 has been divided by the total active agricultural population. Average annual

[3]In other (for example Mediterranean) climatic regions, these crops could not be cultivated without irrigation as they adapted badly to more arid climates (Garrabou 1994; Tortella 1994 and González de Molina 2001).

European growth in this period was 4.23%, the highest rate in the last two centuries.

Labor productivity growth was especially fast until the early 1990s, increasing from then on somewhat more slowly. This sustained growth took place, however, very differently from a time perspective. Production increased substantially until the beginning of that decade and then stabilized. Meanwhile, the fall in the active agricultural population was prolonged and sustained, and especially fast after the 1980s.

The growth of production in the first stage, 1950-1992, resulted from a strong increase in the use of modern inputs, such as fertilizers and machinery, while the cultivated land area fell slightly. In the second stage of stagnant production, 1992-2005, not only did cultivated land decrease further, but so did the number of tractors and livestock units and, particularly, the use of fertilizers.

The evolution of labour productivity is disaggregated by country in Table 2, which shows very different patterns.

Throughout the period, Western European countries had productivity levels far above European averages, and productivity growth higher than the Continental norm. This group of countries displays interesting variations in evolution. Some, such as the United Kingdom and the Netherlands, despite currently having the highest labour productivity levels on the Continent, have seen their growth decelerate in recent years (Brassley 2000). Others, for example France and Denmark, have been able to maintain high growth rates.

The Nordic countries have had greatly varying levels of agricultural productivity, but ranging around the European average. From 1950 to 2005 their growth was lower or similar to European growth, meaning a loss of their positions on the Continent. Norway was below the European average while Finland was slightly above. Sweden remains above this average, but in 1962 more than doubled it.

Table 1
Labour productivity, production and productive factors in European agriculture, 1950-5005

Europe	Ag. labour productivity ($)	Net ag. prod. ($000,000)	Active ag. pop (000 people)	Arable land and permanent crops (000 hectares)	Tractors (000 units)	Fertilizers (000 tonnes)	Live animals (000 units of cattle)
1950	1,397	92,868	67,300	150,388	962	6,983	132,456
1962	2,378	130,187	54,592	151,854	4,002	14,803	155,744
1972	3,815	157,032	41,125	142,750	6,312	26,050	163,866
1982	6,173	188,969	30,418	140,337	8,684	31,769	175,453
1992	8,726	191,122	22,143	136,378	9,923	23,995	162,536
2000	11,664	195,073	16,762	131,313	9,595	19,568	148,442
2005	13,627	192,444	14,218	126,741	9,806	19,534	142,230
Annual rates of growth							
1950-1992	4.46	1.73	-2.61	-0.23	5.71	2.98	0.49
1992-2005	3.49	0.05	-3.35	-0.56	-0.09	-1.57	-1.02
1950-2005	4.23	1.33	-2.79	-0.31	4.31	1.89	0.13

Net agricultural production is in millions of international dollars, at 1999-2001 prices. All the data are triennial averages, except agricultural labour productivity, fertilizers, tractors, live animals, arable land and agricultural active population for 1950. See the Appendix for more details on the data or countries included.
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

Table 2
Agricultural labour productivity, 1950-2005 (dollars per worker)

	1950	1962	1972	1982	1992	2000	2005
GFR/Germany	1,591	3,988	7,911	12,290	17,237	26,003	31,037
GDR	1,881	2,985	5,442	7,401	-	-	-
Austria	1,244	3,078	5,488	9,539	11,351	16,555	18,284
Belgium-Luxembourg	4,547	9,906	19,008	30,185	42,341	53,281	58,360
Denmark	4,661	8,818	11,584	20,757	28,575	40,342	49,308
France	1,858	5,452	9,597	16,436	25,659	37,584	44,881
Ireland	2,840	4,435	7,464	12,521	19,671	21,948	21,625
Netherlands	4,275	9,675	18,142	28,311	32,267	33,997	35,635
Switzerland	3,581	5,613	7,641	10,494	10,158	11,559	12,859
United Kingdom	5,904	9,857	15,051	19,119	23,660	25,428	26,132
Western Europe	**2,655**	**6,285**	**10,756**	**17,397**	**24,040**	**30,522**	**33,774**
Greece	1,792	1,837	2,974	4,613	6,788	8,057	8,355
Italy	1,522	2,863	5,290	8,979	12,795	19,122	23,006
Portugal	1,211	1,752	2,215	1,897	3,490	4,377	4,892
Spain	1,225	2,017	3,451	6,127	10,361	16,043	18,001
Mediterranean E.	**1,419**	**2,334**	**3,961**	**6,255**	**9,551**	**13,459**	**15,259**
Finland	1,093	2,674	3,715	5,705	7,798	10,666	13,476
Norway	2,115	3,163	4,758	6,453	7,815	9,082	10,190
Sweden	3,665	5,111	6,883	9,816	11,511	16,050	18,137
Nordic Europe	**2,140**	**3,634**	**5,004**	**7,374**	**9,186**	**12,197**	**14,297**
Albania	n.a.	472	593	691	697	1,048	1,191
Bulgaria	607	1,221	2,597	4,673	6,240	10,195	12,022
Czechoslovakia	1,324	2,212	3,824	5,156	6,549	6,608	7,576
Hungary	1,153	1,803	3,386	6,346	7,471	10,018	12,634
Poland	1,033	1,438	1,835	2,432	2,805	3,290	3,920
Romania	392	656	1,169	2,182	2,504	3,531	5,835
Yugoslavia	363	545	888	1,935	3,180	4,038	5,323
Central and Eastern Europe	**787***	**1,030**	**1,631**	**2,703**	**3,332**	**4,073**	**5,138**
Europe	**1,397***	**2,378**	**3,815**	**6,173**	**8,726**	**11,661**	**13,627**

* Albania is not included
The data for the groups of countries are weighted averages. All the figures are calculated using triennial averages (net production at international prices in dollars for 1999-2001, divided by the total active agricultural population). For more details, see the Appendix.
The German Federal Republic, the German Democratic Republic and the reunified Germany are not included in any group due to border variations.
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

In 1950 productivity in the Mediterranean countries (except Italy) was lower than in Europe as a whole, and two different trajectories are apparent. On the one hand, productivity growth in Spain and Italy has been very high and far above Continental rates, locating them clearly above the European average since the 1990s. On the other, in 1950 Greece and Portugal had productivity levels very similar to the other Mediterranean countries, but have clearly been outpaced; their current productivity is far beneath the European average.

Lastly, the active agricultural population in the Eastern European countries has been much less productive than in Europe as a whole. Growth from 1950 to 2005 was extremely heterogeneous. Productivity growth in Poland and the Czech Republic was under the European average, while Romania, Bulgaria and Hungary were above the average figures for Eastern Europe. These countries, as well as the Soviet Union, incorporated many of the innovations being adopted by other European countries, generating sharp increases in production between 1960 and 1990 (Diamond *et al.*, 1983).

Consequently, agricultural labour productivity increased in the Eastern countries prior to the fall of Communism. In the 1990s, by contrast, agricultural production declined, due to the collapse of the central planning economy. The transition to a market economy shows great differences in the evolution of labour productivity, although once overcome these countries returned to the path of growth (Macours and Swinnen 2002).

Finally, Table 2 shows that although the growth of labour productivity in different European countries has been extremely important, very significant differences persist in their levels. In 2005 labour productivity in Germany or Western European countries was twice as high as in the Mediterranean or Nordic countries, despite some of the latter having experienced very strong productivity growth. In addition, Western European countries levels of labour productivity were six times higher than the Central and Eastern European countries.

Table 3
Land productivity in European agriculture

	1950	1962	1972	1982	1992	2000	2005
GFR/Germany	952	1,626	2,047	2,458	2,109	2,190	2,105
GDR	778	832	1,195	1,354	-	-	-
Austria	727	1,299	1,473	1,847	1,957	2,248	2,153
Belgium-Luxembourg	1,864	2,660	3,292	4,698	5,346	4,778	4,491
Denmark	893	1,122	1,106	1,404	1,671	1,900	1,916
France	656	1,057	1,433	1,611	1,653	1,691	1,654
Ireland	1,097	1,081	1,598	2,692	3,408	3,267	2,948
Netherlands	3,019	4,126	7,414	10,373	10,654	9,729	8,647
Switzerland	2,600	3,648	4,389	4,822	4,800	4,448	4,545
United Kingdom	966	1,253	1,521	1,922	2,220	2,287	2,208
Western Europe	**884**	**1,270**	**1,666**	**2,033**	**2,217**	**2,249**	**2,169**
Greece	705	831	1,055	1,403	1,576	1,708	1,622
Italy	757	1,093	1,622	1,923	2,055	2,126	2,306
Portugal	562	825	760	681	936	1,257	1,523
Spain	325	447	572	738	909	1,166	1,207
Mediterranean Europe	**540**	**740**	**953**	**1,166**	**1,325**	**1,534**	**1,605**
Finland	402	535	598	698	660	694	702
Norway	936	965	1,102	1,248	1,131	1,125	1,139
Sweden	617	641	688	854	792	859	875
Nordic Europe	**578**	**640**	**704**	**848**	**792**	**837**	**847**
Albania	n.a.	513	586	751	712	930	1,077
Bulgaria	413	600	818	1,006	695	634	619
Czechoslovakia	533	648	847	1,054	1,083	910	947
Hungary	432	562	783	1,058	939	923	1,011
Poland	452	619	787	860	894	871	1,031
Romania	333	403	564	718	618	617	734
Yugoslavia	332	508	672	897	857	827	892
Central and Eastern Europe	**428***	**551**	**727**	**888**	**834**	**800**	**899**
Europe	**616***	**854**	**1,098**	**1,337**	**1,416**	**1,488**	**1,529**

*Albania is not included
The data for the groups of countries are weighted averages. All the figures are calculated using triennial averages (net production at international prices in dollars for 1999-2001, divided by the total active agricultural population).
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

For a better understanding of these differences, labour productivity can be disaggregated into two components: land productivity and land-labour ratio.

Table 3 shows the evolution and levels of productivity per hectare in European agriculture. There is a gradient from high levels of productivity in Germany and the countries of Western Europe to well below the average for Mediterranean countries and especially Nordic and Central and Eastern Europe countries.

Table 4 offers the land-labour ratios. It demonstrates that low land productivity countries, although they have tended to increase their land-labour ratios to achieve high labour productivity, have not reached the high levels of Western Europe. The Nordic or Spanish land-labour ratios have reached the same level as Western countries or Germany, but do not offset their disadvantage in land productivity. The land-labour ratios of the countries of Central and Eastern Europe and some Mediterranean countries such as Greece or Portugal are much lower than the rest of Europe.

2.2. Has the labour productivity of European agriculture converged?

From the sharp increase in agricultural labour productivity, the massive incorporation of new industrial inputs and the biological innovations adopted, it might be assumed that convergence processes have taken place at all levels. The access to technology capable of generalized application to the entire continent may have fostered this rapprochement. However, so far this convergence has not apparently occurred. Now, the task is to determine accurately whether the productivity levels of agricultural labour converged.

Firstly, let us observe σ-convergence and then β-convergence, following the methodology of Barro and Sala-i-Martin (1992).

Table 4.

Land-labour ratio in European agriculture, 1950-2005

	1950	1962	1972	1982	1992	2000	2005
GFR/Germany	**1.67**	**2.45**	**3.86**	**5.00**	**8.18**	**11.87**	**14.76**
GDR	**2.14**	**3.58**	**4.55**	**5.47**	**-**	**-**	**-**
Austria	1.71	2.37	3.73	5.17	5.80	7.37	8.49
Belgium-Luxembourg	2.44	3.72	5.77	6.43	7.93	11.19	13.01
Denmark	5.22	7.86	10.47	14.78	17.09	21.23	25.75
France	2.83	5.15	6.69	10.20	15.53	22.26	27.17
Ireland	2.59	4.10	4.67	4.65	5.77	6.74	7.34
Netherlands	1.42	2.34	2.45	2.73	3.03	3.50	4.15
Switzerland	1.38	1.54	1.74	2.18	2.12	2.60	2.83
United Kingdom	6.11	7.86	9.89	9.95	10.66	11.12	11.85
Western Europe	3.01	4.95	6.45	8.55	10.84	13.58	15.58
Greece	2.54	2.21	2.82	3.29	4.31	4.72	5.15
Italy	2.01	2.62	3.26	4.67	6.22	9.00	9.98
Portugal	2.15	2.12	2.92	2.78	3.74	3.48	3.22
Spain	4.09	4.51	6.03	8.30	11.40	13.75	14.91
Mediterranean E.	2.70	3.15	4.16	5.36	7.21	8.77	9.51
Finland	2.72	4.99	6.21	8.17	11.82	15.36	19.20
Norway	2.26	3.28	4.32	5.17	6.91	8.08	8.95
Sweden	5.94	7.97	10.00	11.50	14.50	18.69	20.74
Nordic Europe	3.70	5.68	7.10	8.69	11.59	14.57	16.88
Albania	n.a.	0.92	1.01	0.92	0.98	1.13	1.11
Bulgaria	1.36	2.03	3.17	4.65	9.06	16.08	19.42
Czechoslovakia	2.50	3.41	4.51	4.89	6.05	7.26	8.01
Hungary	2.63	3.20	4.32	6.00	7.97	10.84	12.52
Poland	2.29	2.32	2.33	2.83	3.14	3.78	3.80
Romania	1.28	1.63	2.07	3.04	4.05	5.72	7.98
Yugoslavia	1.09	1.07	1.32	2.15	3.72	4.89	5.98
Central and Eastern Europe	1.68*	1.87	2.24	3.04	4.00	5.09	5.72
Europe	2.24*	2.78	3.47	4.61	6.02	7.58	8.56

*Albania is not included
The data for the groups of countries are weighted averages. All the figures are calculated using triennial averages. The data for Central and Eastern Europe in 1950 do not include Albania.
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

Table 5. Dispersion measures of agricultural labour productivity

	Variance of logarithm of labour productivity	Coefficient of Variation	Theil	Herfindahl	Gini
1950	0.6073	0.7223	0.0763	0.0681	0.2689
1955	0.6454	0.7119	0.0754	0.0674	0.2686
1960	0.6422	0.7449	0.0802	0.0695	0.2511
1965	0.6420	0.7487	0.0807	0.0698	0.2563
1970	0.7023	0.7937	0.0884	0.0728	0.2580
1975	0.6423	0.7804	0.0846	0.0719	0.2459
1980	0.6767	0.8041	0.0894	0.0735	0.2583
1985	0.6551	0.7822	0.0861	0.0720	0.2610
1990	0.6040	0.7482	0.0797	0.0697	0.2644
1995	0.6742	0.7981	0.0890	0.0731	0.2877
2000	0.6646	0.7692	0.0846	0.0711	0.2891
2005	0.5981	0.7593	0.0811	0.0705	0.2764

All the figures are calculated using triennial averages, except 1950. Furthermore, the same number of countries has been maintained, aggregating the individual country data following the dissolution of Yugoslavia and Czechoslovakia.
Source: Authors' elaboration, from FAOSTAT (2009)

Table 5 shows that the dispersion of productivity has increased gradually or has been maintained since the 1950s, and thus σ-convergence has not taken place[4]. An increase can be observed in the dispersion of agricultural labour productivity until 1980, as noted by the variance of logarithm, coefficient of variation and Theil and Herfindahl indexes. Analysing the 1980s, the dispersion of this type of productivity, measured using these variables, decreased. After 1990, the dispersion among European countries continued to grow. The Gini coefficient measured a slight decrease until 1975, and from that year onwards rose, especially in the 1990s.

The existence of β-convergence[5] must now be checked, using the classic exponential cross-section equation of β-convergence (Barro and Sala-i-Martin 1992). The endogenous variable is productivity growth in the whole period and the explanatory variable is its initial level in 1950:

$$ctoproduct_i = c - [(1 - e^{-\beta T}) / T].\log(product_{50i}) + u_i \, .$$

The value of the estimator of β is 0.000237, and this value is not significant at 10%. In other words, initial productivity in 1950 does not explain growth along the entire sample period.

Figure 1 also shows that despite the relation being inverse, the slope of the trend is very slight and the coefficient of determination is close to 0. Thus, there is evidence of neither β-convergence nor absolute convergence.

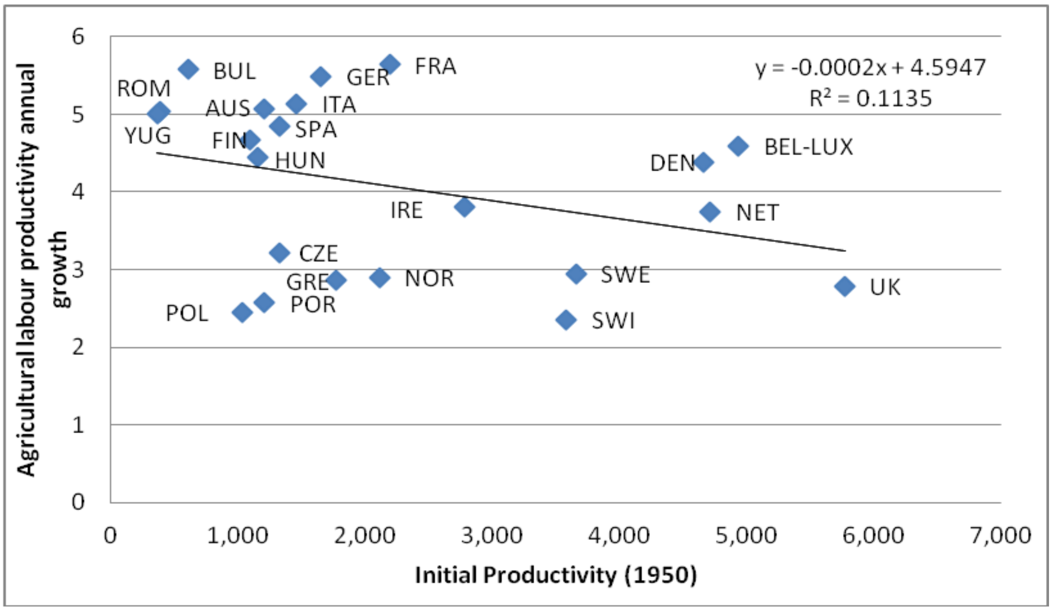
Now, the question is how to explain why the differences in productivity existing within the continent of Europe in 1950 did not decrease until the early XXI century. In other words, why have such important differences in agricultural productivity levels in Europe been maintained until today?

[4]To calculate this dispersion, the countries succeeding the former Yugoslavia and Czechoslovakia following their dissolution in 1992 and 1993, respectively, have been added to maintain the same number of countries. Furthermore, the two Germanys have been added for the period 1950-1990.

[5] To calculate $\beta - convergence$ countries have been added as for $\sigma - convergence$.

Figure 1

Initial productivity (1950) versus average annual growth, 1950 – 2005



Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

3. Theoretical approach and method

Labour productivity is the partial productivity of agriculture which has grown fastest in Europe since World War II (Henrichsmeyer and Ostermeyer-Schlöder, 1988). This growth is directly linked to structural change, since agricultural labour is the denominator of this variable. Consequently, both increased production and reduced labour, or a combination of the two, could have raised productivity.

Labour productivity levels are determined by many causes, from factor endowment and technology to institutions or geography. As in the literature on economic growth and, recently, in economic history as well, there exist both proximate and fundamental causes to explain agricultural productivity variations (Crafts, 2010). The present approximation attempts to combine both types of variables.

Proximate causes are the variables included in any production function of the agricultural sector, except, obviously, the labour factor, which is already the labour productivity denominator. These productive factors have normally been included in all estimations of agricultural productivity (Hayami and Ruttan, 1985; Kawagoe *et al.*, 1985; Gallup, 1998 or Griliches, 1964, among many others). The present analysis takes account of all the productive factors in traditional agriculture (land) and of modern inputs from other sectors, such as fertilizers and machinery. Machinery and fertilizers have significantly increased their importance in the productive process, in line with agricultural development (Grigg 1992; Federico 2005a). The land area equipped for irrigation is another crucial variable to measure the differences in agricultural labour productivity in the period subsequent to World War Two, because of its importance in overcoming unfavourable geographical conditions in certain semiarid European regions.

Less commonly, livestock variables have been included in the estimation of agricultural productivity. These affect production in two ways: as capital which, in addition to producing goods, lasts more than one financial year, and as a driving force in farming. In the years under analysis, in addition to a radical reduction of the contribution of animals to rural labour, their importance as capital increased, as intensive livestock farming emerged (Hayami and Ruttan 1985; Godley and Williams 2009).

Human capital is one of the variables most commonly studied to observe differences in agricultural labour productivity (Hayami and Ruttan 1985; Nguyen 1979). This is a crucial variable to explain such differences, above all by comparing developed and developing countries.

The fundamental causes of modern economic growth are also taken into account in the present analysis. Certain institutions can significantly affect productivity, influencing for example the propensity to trade, the adoption of technology, investment incentives or human capital skills. Prominent among these determinants are the functioning of product or factor markets, agricultural credit, foreign trade policy or economic policy.

It is a complex task to measure all possible channels of institutional influence upon the productivity of such a large sample of countries, and thus the focus here is on those most important and easiest to observe. In other words, membership of either the European Union (formerly the European Economic Community) or of the communist bloc, led by the Soviet Union. These two institutional frameworks have had extremely significant consequences, which for some authors are essential to the understanding of agricultural output in Western and Eastern Europe (Houpt et al., 2010). One alternative possibility is to measure the influence of the institutional framework in agriculture through the Nominal Rate of Assistance, elaborated by Anderson and Valenzuela (2008). However, the lack of data for the complete sample (approximately 42% of the observations are lacking) means that certain significant results have been unable to be obtained.

EU membership has entailed the adoption of the Common Agricultural Policy (CAP) and access to the common market of member countries. The CAP has radically altered their agricultural panorama, involving a partial substitution of market mechanisms by public policies.

The creation of firstly a customs union and secondly a single, strongly protected, market has greatly facilitated increased trade among members and import substitution (Pinilla and Serrano, 2009). Export subsidies and trade protectionism have guaranteed the objective or minimum prices established by the European Commission, to provide help to farmers and to support the agricultural sector by trading at prices above international levels (Tracy 1989; Ritson 1997; Andreosso-O'Callaghan 2003; García Delgado *et al.* 2005). The intention here is to measure their possible influence on labour productivity.

In the Soviet bloc land was collectivized, rationing was introduced, and products were requisitioned; essentially, the market economy was replaced by central planning. Land was either transferred to the state or maintained in private hands, obliging owners to join cooperative enterprises while allowing a small part of their production to remain strictly private. Collective farms increased mechanization, yet despite lower labour requirements, the collectivized farms "became employers of last resort, providing a meagre subsistence to women and children, the old and the infirm" (Allen 2003: 100). The Soviet countries also threatened peasants failing to comply with the planners' orders, producing general discontent with the system and a tendency towards passive protest.

Moreover, production did not usually equate with demand. From the economic point of view, socialist agriculture had great structural problems of incentivisation. This was because, following collectivization, all agricultural workers were guaranteed a minimum income, with little incentive to work harder[6]. Similarly, efficient agricultural policies were lacking, further causing state agriculture to perform beneath its potential (Gregory and Stuart 2001; Allen 2003; Federico 2005a)[7]. Membership of the Soviet bloc has frequently been used to measure the undermining of agricultural productivity by the communist system (Alauddin et al. 2005; Federico 2005b).

Geography is another of the fundamental causes of growth. Geographic variables may directly affect agriculture through temperature, rainfall, sunshine, pestilence and diseases, soil, orography or latitude (Gallup 1998; Grigg 1992; Crosby 1986; Asenso-Okyere*et al.* 2011).

While few studies include orographical factors to explain agricultural productivity, these may have diverse effects. As altitude rises temperature falls, harming agricultural output (Grigg 1982; Federico 2005a). More decisive may be the fact that steeper slopes demand greater intensity of labour, and rugosity is thus included here as an explanatory variable, to measure the ruggedness of land. Several studies have underlined that a highly uneven terrain prejudices agriculture and other economic activities (Nunn and Puga, 2007; Ayuda *et al.*, 2010).

A lack of water can also hinder productivity; for some countries it is a clear obstacle to agricultural development (González de Molina 2001; Clar and Pinilla, 2009). Water is an essential resource for plant growth, and the impact on output is huge unless appropriate measures are taken. A measurement of evapotranspiration, used previously by Mundlak and Hellinghausen (1982), is therefore included.

Closely linked to the water deficit is the climate and natural vegetation of each country. Some research includes measurements of the bioclimatic landscape, to determine the disadvantage for tropical, polar or temperate countries (Gallup 1998). Such landscapes are sets of climate, flora and fauna common to a region. Extreme bioclimatic landscapes, such as the polar or tropical, suffer the greatest disadvantages.

[6]As Federico (2005a: 208) warns, of the variable part of peasant income (a productivity-related bonus): "(this) depended on the performance of the whole team, which usually numbered hundreds if not thousands of workers. There were no incentives for peer-monitoring, and external monitoring was quite expensive in terms of time (i.e. of foregone output) and open to corruption and patronizing".
[7] On the inconsistency of Polish agricultural policy, see Landau and Tomaszewski (1985).

The method and variables employed to determine which factors influence agricultural labour productivity are now explained. The estimation was performed using a linear function, including the variables in logarithms and employing the data panel technique. The functional form of the estimation has a clear antecedent in the work of Christensen *et al.* (1973). That is to say, it is based on the production function *translog*[8], to which we have added several institutional and geographical variables. The sample comprises 32 European countries, with annual data for 1950-2006[9].

The equation proposed is:

$$\log(product_{it}) = \alpha_0 + \sum_{i=1}^{n} \beta_i \log(x_{it}) + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \log(x_{it}) \log(x_{jt}) +$$

$$+ khumans\,\alpha_1 + khumant\,\alpha_2 + com_{it}\alpha_3 + eu_{it}\alpha_4 + geo_i\alpha_5; \beta_{ij} = \beta_{ji}$$

The endogenous variable ($product_{it}$) measures output per worker in the agricultural sector; it is the quotient between net agricultural production at international 1999-2001 prices in dollars and the active agricultural population[10]. The correct measurement of the labour factor would be of hours worked, but data for this variable are not available[11].

The x matrixes are all those variables aimed at approximating the impact of productive factors on labour productivity (land and capital) and were obtained from FAOSTAT (2009) and FAO (1948-2004)[12]. $Land_{ij}$ (A) is the quotient between the area of arable land and permanent crops and the active agricultural population. $Livestock_{ij}$ (L) is the stock of live animals, calculated using the weightings of Hayami and Ruttan (1985) and divided by the active agricultural population. $Fertil_{ij}$ (F) is the quotient between the sum of the consumption of potassium, phosphate and nitrogen fertilizers and the active agricultural

[8] The Cobb-Douglas production function is the same function, assuming $\beta ij= 0$. The production function used (*translog*) relaxes the implications of additivity and homogeneity (Christensen et al. 1973).
[9] See Appendix.
[10] See Appendix.
[11] EUROSTAT offers a variable for European agriculture called the Annual Work Unit. This variable is not available for either all the countries or for the entire temporary sample. Furthermore, the calculation of this variable takes ad hoc assumptions into account. Therefore, the present study prefers to maintain the agricultural active population as the relevant variable.
[12]The data between 1950 and 1960 are based in FAO (1958-2004). See Appendix for further information.

population. Maq_{ij} (M) is the quotient between the number of tractors and the active agricultural population. $Irri_{ij}$ (I) is the area per worker equipped for irrigation.

The measure of human capital shows the Gross Enrolment Ratio in secondary and tertiary education (*khumans* and *khumant*). The data were elaborated using data from the World Development Indicators (2011) and Mitchell (2007)[13].

Two variables proxy the effect of institutions on productivity: Com_{ij} is a dummy which takes the value of 0 if the country does not have a centrally planned economy and 1 otherwise; eu_{ij} is another dummy which takes the value of 0 if the country does not belong to the EU (formerly the EEC) and 1 otherwise.

Physical geography, geo_i, is measured in two ways, firstly by including two variables, the first of which is Rug_i *(Ruggedness)*, the measure of the ruggedness of terrain, calculated using a georeferenced system, GTOPO30, which determines altitude with a resolution of approximately one kilometre. The variable is obtained from the standard deviation of each cell from the eight adjoining cells. The national value is proxied by the average of all the standard deviations of the country.

The second variable, Fwd_i *(Water Deficit Factor)*, is the quotient between real evapotranspiration and potential evapotranspiration, distributed in the European continent through huge regions which adopt the same value for this variable (Linneman*et al.* 1979). For a national value of *Fwd*, the measurement performed was weighted by the proportion of each of these great regions within the surface area of each country.

[13]See Appendix.

Table 6
Summary statistics of the explanatory variables and number of countries within each institutional variable

		1950	1962	1972	1982	1992	2000	2005
Land per worker	Mean	2.69	3.48	4.51	5.62	7.20	9.21	10.98
	St. Dev.	1.42	2.08	2.70	3.41	4.31	5.68	7.19
Fertilizers per worker	Mean	0.20	0.50	1.12	1.57	1.44	1.52	1.77
	St. Dev.	0.23	0.48	0.89	1.12	1.26	1.34	1.48
Tractors per worker	Mean	0.03	0.14	0.30	0.47	0.61	0.74	0.88
	St. Dev.	0.06	0.14	0.25	0.36	0.42	0.50	0.60
Live animals per worker	Mean	3.32	5.12	7.42	10.05	12.28	15.02	16.70
	St. Dev.	2.53	4.32	6.75	8.82	11.32	14.72	15.84
Irrigation (ha.) per worker	Mean	0.13	0.19	0.35	0.61	0.93	1.29	1.41
	St. Dev.	0.17	0.21	0.34	0.60	0.86	1.17	1.41
Human capital (secondary)	Mean	39.16	64.28	74.68	84.12	96.30	102.84	99.81
	St. Dev.	26.81	30.19	16.63	15.83	13.96	19.06	11.10
Human capital (tertiary)	Mean	3.70	7.32	16.15	22.79	30.71	47.05	57.60
	St. Dev.	1.60	4.86	8.75	11.86	11.60	15.77	17.97
Institutions (number of countries)	Communist	7	8	8	8	2	1	0
	EU	0	5	5	9	11	14	19

Source: Authors' elaboration, with thanks to FAOSTAT (2009) and FAO (1948-2004)
The data are triennial averages, except 1950 and the data for institutions. Albania is omitted in 1950 because of the non-availability of data. To maintain the same number of countries, the data of the ex-Yugoslav republics or the Czech Republic and Slovakia have been aggregated after 1991 and 1992, respectively, and the data of the two German Republics have been aggregated prior to 1990.

As an alternative, the influence of geography was also measured, through the percentage of the area of each country in distinct bioclimatic regions (western, Mediterranean and polar)[14]. The estimation omits the so-called western biome, formed by the bioclimatic zone of wide leaf forests, mixed forests and temperate conifer forests, taken as reference for comparison with the Mediterranean biome (the aggregation of temperate grasslands, scrubland and Mediterranean forests) and the polar biome (comprising tundra and taiga) (CIESIN 2007).

Table 6 shows the mean and standard deviation for the European continent of the explanatory variables used in the econometric model. Firstly, capital endowment per worker (whether in machinery, fertilizers, irrigation or animals) has increased very significantly. The increase in land per worker was also remarkable, rising by 300%. Lastly, the differences in the use per worker of these factors, measured by the standard deviation, tended to increase, except in human capital at the secondary level of education.

For the institutional variables employed, Table 6 reflects the number of countries included in each case throughout the period. It is well known that the tendency has been toward a progressive amplification of the EU, while the formerly Communist bloc remained stable until its dissolution in the early 1990s. For 1950 there are seven Communist countries.[15]

The technique used to obtain the final results is based on the data panel method; it improves the efficiency of the estimators, since it accumulates more information on variations in the data, controls for individual heterogeneity, identifies and measures effects which time series or cross-section analyses do not detect. Moreover, it reduces the problem of omitted variables (Baltagi 2005; Hsiao 1999). Consequently, the data panel technique is more precise than its time series or cross-section counterparts.

4. Results

The econometric results were obtained by OLS estimation with pooled data, and also by random effects and fixed effects to check which estimation was

[14] A bioclimatic zone or biome is a zone of the planet with a common climate, vegetation and fauna.

[15] See Appendix to observe how the paper elaborates the data for agricultural production. For 1950, there are no data for Albania.

optimal. The Breusch-Pagan LM test, used to choose between the OLS estimation and random effects, rejected the null hypothesis which corresponds to a OLS estimation, namely that random effects was preferable to an estimation based on a pooled data panel. Moreover, the choice was tested when estimating between OLS and fixed effects with the F-test.

This rejected the null hypothesis that it is preferable to use the grouped data panel, as the statistic's value was F =128.02 (Greene 1997). As a result, the OLS estimation is not included in the results table.

Two relatively common econometric problems, heteroskedasticity and autocorrelation, are tackled by the Wald (Greene 1997) and Wooldridge tests (Wooldridge 2002), respectively. In both cases the null hypothesis of homoskedasticity and non-autocorrelation is rejected.

The first column of Table 6 shows the random effects estimation using the first way of measuring geography, namely with the variables *rug* and *fwd*. The second column also includes the estimation of random effects, although the influence of geography is calculated using the bioclimatic zones. These estimations are compared with those of fixed effects (Column 3). Furthermore, the Hausman test reveals that the differences between estimators is significant: comparing column (1) and (2) against (3). Both have a null p-value, and thus the best estimation is that of fixed effects. The inconvenience of this procedure is that it omits the geographical variables constant over time.

Both heteroskedasticity and autocorrelation can be resolved using the estimation in Column 4 (Panel Corrected Standard Error). This estimation is performed using variables transformed into deviations according to their individual, temporal and overall average. The PCSE estimation is chosen, following Beck and Katz (1995), as they compare the standard errors of PCSE with FGLS (Feasible Generalized Least Squares). The PCSE standard errors are more precise than the other estimations.

Table 7 Econometric results

	RE	RE	FE	PCSE
Land (a)	.4243***	.3146***	.5803***	.4281***
	.0963	.0932	.09636	.1363
Livestock (l)	.0611***	.0606***	.04662***	.0426***
	.0048	.0048	.0044	.0063
Fertilizer (f)	.1352**	.1410***	.1949***	.1050**
	.0534	.0528	.0488	.0519
Machinery (m)	.1989***	.2203***	.0716**	.1064**
	.0337	.0328	.0318	.0444
Irrigation (i)	.1361***	.1582***	.1375***	.1511***
	.0253	.0262	.0255	.0417
khumans	.0461***	.0580***	.0601***	.0220
	.0109	.0108	.0115	.0142
khumant	-.0347***	-.0248**	-.0283***	.0245**
	.0099	.0097	.0095	.0122
Communist	-.1211***	-.1572***	-.0405**	-.0437*
	.0191	.0186	.0193	.0239
EU	.0681***	.0615***	.0553***	.0472***
	.0125	.0123	.0115	.0128
βaa	-.0153	.0199	-.0017	.0973
	.0455	.0450	.0452	.0616
βff	-.0452***	-.0465***	-.0635***	-.0290***
	.0169	.0166	.0152	.0098
βmm	.0038	.0074	-.0115**	-.0148**
	.0058	.0057	.0054	.0071
βll	-.0009***	-.0008***	-.0007***	-.0008***
	.0002	.0002	.0001	.0002
βii	.0257***	.0276***	.0213	.0174**
	.0044	.0045	.0044	.0069
βam	-.0537***	-.0563***	-.0144	-.0262
	.0126	.0123	.0118	.0161
βaf	.0119	.0164	-.0062	-.0143
	.0174	.0173	.0159	.0141
βal	-.0039*	-.0041*	-.0053***	-.0011
	.0022	.0022	.0020	.0029
βmf	-.0641***	-.0663***	-.0407***	-.0324***
	.0115	.0114	.0105	.0111
Bml	.0029*	.0030*	.0001	-.0001
	.0016	.0016	.0015	.0018
Bfl	-.0003	-.0007	.0021	.0008
	.0016	.0017	.0015	.0012
Bia	-.0061	-.0190*	-.0453***	-.0508***
	.0107	.0108	.0113	.0164
Bim	.0054*	.0065**	.0031	.0067
	.0030	.0030	.0027	.0042
Bif	-.0022	.0007	.0052	.0094
	.0074	.0073	.0067	.0078
Bil	-.0013	-.0011	.0013	.0005
	.0009	.0009	.0008	.0011

Rug	.0023***	-	-	-
	.0006			
Fwd	.4415***	-	-	-
	.0980			
Parbpolar	-	-.4326***	-	-
		.0652		
Parbmediter	-	-.2113***	-	-
		.0616		
Time	.0041***	.0028***	.0067***	-
	.0007	.0007	.0007	
Constant	7.2836***	8.1712***	7.5113***	.0001
	.2135	.1622	.1971	.0041
R^2 within	0.9755	0.9752	0.9770	0.8273
Nº observations	1,415	1,415	1,415	1,415

The data below the coefficients are the standard deviations. The coefficients *, ** and *** are significant at 10, 5 and 1% respectively. The variables in the PCSE estimation are transformed into deviations according to their individual, temporal and overall average. The interaction coefficients β have a subscript corresponding to the first five variables. All the variables are in logarithms, except *com* and *eu*. The letters in parentheses, close to the name of the variables, correspond to the sub-index in the group of β. The value of R^2 within the PCSE estimation corresponds to R^2.

The first interesting result is the importance of the land per agricultural worker variable (*land*), with a coefficient of 0.4281, the sign expected and a significant coefficient. This underlines that the increase in the land/labour ratio was the strongest determinant of labour productivity differences.

The second half of the XX century saw a highly varied and intensive process of rural exodus in Europe (Collantes and Pinilla, 2011). In short, and as Table 1 shows, the cultivated land area fell, but by much less than the labour force; the most important factor in productivity differences was the exit of workers from the sector.

As a result, the driving force behind agricultural productivity growth came from outside agriculture itself. The culmination of industrialization in many countries or its rapid advance in others, together with tertiarisation, involved a formidable rural exodus, reducing for the first time in the majority of European countries not only the share of agricultural workers in the total active population, but also its size. The productivity of agriculture was thus directly conditioned by the rhythm of the economic transformations outside it.

This in turn meant an increase in the average size of farms (Federico 2005a, Fennell 1997), exploiting the technology available to intensively mechanize production. Modern agriculture was thus able to achieve certain economies of scale, much more difficult to attain traditionally.

Of course, this central role of increased land area per worker demanded fundamental changes in agriculture itself. More land per worker was only viable insofar as fewer workers could perform the same tasks: workers were more efficient. Tractors and harvesters were from this perspective crucial, and thus the positive sign, significance and the relatively high coefficient for tractors per worker are unsurprising to explain the differences in labour productivity.

The same is true of livestock units per worker, although this variable reflects two very different processes. Firstly, the progressive disappearance of field working animals in Europe, replaced by machines (Grigg 1992). At the same time, however, new processes in livestock breeding, dairy, poultry, pork and beef production, meant the industrialization of an activity previously highly labour-intensive, one in which substantial economies of scale were achieved.

New livestock breeding methods allowed this activity to dissociate itself from the soil and the ecological limits for its development in countries with less favourable natural conditions (Pinilla and Clar 2011). Such countries, for which this new activity has become highly important, have exploited the opportunity to attain higher productivity levels per worker.

Briefly, it is also natural that the use of fertilizers shows the expected positive sign and is significant; their contribution to raising productivity is considerable.

Irrigation is another crucial variable to explain the differences in agricultural labour productivity, since it has a positive sign and is significant.

Human capital is important in explaining differences in labour agricultural productivity. Both variables are significant and have the expected sign in the PCSE.[16]

With regard to institutions, in this estimation both variables are significant at 1% and show the expected sign. The negative sign for communism implies that this system prejudiced productivity in various ways, for example by land collectivization and product requisition, the control of production and prices by planners, threats to the peasants who failed to comply with the plan or the lack of work incentives (Allen 2003; Federico 2005a). In general, this institutional framework maintained a significant level of redundant labour in both agriculture and other activities; in other words, the agricultural labour force fell, although by less than in Western Europe (Gregory and Stuart, 2001).

Membership of the European Union (EU) has been of greater importance, generating not only a stable and common institutional framework but also guaranteed minimum prices and subsidies. These were linked, at least until the 1990s, to production levels. Furthermore, EU affiliation has meant the protection of trade for the primary sector in Europe, excellent access to member country markets and subsidies to exports to third countries, generating prices in excess of international market prices (García Delgado *et al.* 2005; García Grande 2005; Serrano and Pinilla, 2011).

It is consequently reasonable to assume that this policy has provided security, stability and improved incomes to European farmers, who have thus been able to adopt the new technologies available at an impressive rhythm and scope.

[16] We attempt to use Barro-Lee's average years of schooling from the WDI (2011). This variable is not significant and we prefer to include the Gross Enrolment Ratio in the final regressions.

The variables β_{ij}, listed in Table 7, are the products between the first four inputs. The negative sign in the quadratic coefficients of fertilizers, machinery and livestock show the decreasing returns of scale for these inputs. In addition, machinery and fertilizers are substitutes, owing to the negative sign of their cross coefficient[17].

The geographical variables, rugosity and aridity, are significant and the first of these does not display the expected sign. Ruggedness negatively affects productivity, as countries with more rugged terrain find it more difficult to perform agricultural tasks. This in turn has historically produced greater livestock specialization in mountainous zones.

For the variable *Fwd*, the closer real evapotranspiration is to potential evapotranspiration, the greater is productivity, as precipitation will be greater and more regular as this quotient approaches unity. This direct relation between *Fwd* and productivity is reflected in the positive sign and its significance, and thus a direct relation can be observed between this variable and labour productivity.

Irrigation has meant improving productivity in agriculture in the southern European countries. For example in Spain, one of the driest countries in Europe, irrigated farming accounts for less than one-third of the agricultural land area, but for over two-thirds of production (Pinilla, 2005).

For the alternative model proposed to estimate the influence of physical geography through the importance of the bioclimatic zones in each country, the results obtained (Column 2 in Table 7) show a significant disadvantage for the polar bioclimatic zones (parbpolar) and the Mediterranean zone (parbmediter) compared to the western zone, which is the reference. This estimation helps to confirm the importance of aridity as a crucial variable to take into account when explaining the differences in European agriculture.

It has not been possible to introduce any variable to proxy the influence of biological innovations on European agriculture, especially the selection and hybridisation of seeds and the introduction of new varieties (Olmstead and Rhode 2008; Pujol, 2011). Nevertheless, it is reasonable to assume that these changes, together with the use of fertilizers, pesticides and herbicides have

[17] Allen (2009, p.425) explained, regarding these estimated translog parameter values, that “their economic significance lies in their implications for elasticities of substitution”.

softened the impact of the natural environment on modern European agriculture (Grigg 1982).

This said, the new techniques employed and the greater capitalisation of the sector after World War Two have had extremely negative environmental consequences, such as the widespread contamination produced by fertilizers, the loss and degradation of natural spaces or the energy inefficiency of this type of agriculture.

5. Conclusions

In the last fifty years agriculture has experienced far-reaching transformations, causing the greatest increase in labour productivity in the last two centuries. Despite such growth, no productivity convergence process is evident among the distinct European countries.

The results underline the crucial role of land endowment per worker in explaining labour productivity differences. Since the cultivated area fell slightly in most European countries, the sharp differences in the land/labour ratio were marked above all by the distinct intensities of the rural exodus process, and by initial differences.

The results of the present study can be compared with other analyses of the differences in agricultural productivity for previous periods in Europe. Van Zanden (1991) shows that between 1870 and 1914 the adoption of land-saving technologies was the most important factor in agricultural productivity growth. O'Brien and Prados (1992) established that the principal differences in productivity per worker resulted from the distinct land-labour ratios. They further underline how far Western European countries differed from their Mediterranean counterparts.

The increase in land endowment per worker was also accompanied by extremely intensive mechanization. Differential capital endowment per worker, fertilizers and, above all, tractors and harvesters, were thus key. In conclusion, the continuous exodus of labour power from the sector, coupled with the increased use of productive factors originating in other sectors of the economy, caused the efficiency of agricultural workers to rise. The different relative importance of these processes across countries largely explains why labour productivity did not converge.

These results enrich the debate about the relationship between economic development and agricultural transformations. The acceleration of economic growth and the advanced stage of demographic transition generated a strong demand for labour in industry and the service sector. New technological options (mainly self-propelled machines) meant that the response to the rural exodus was intensive mechanization on Europe’s farms. The differences in agricultural labour productivity in Europe are therefore partially conditioned by distinct levels of development in different countries.

In turn, institutions have apparently conditioned differences in productivity. A direct relation is detected between membership of the EU and the productivity of agricultural labour. By contrast, this relationship is reversed in the case of Communist bloc membership. This demonstrates the importance of the institutional framework in explaining differences in agricultural productivity. Furthermore, these results clarify the debate on state intervention in agriculture. EU policies tended to raise agricultural productivity, while the total intervention practiced in the centrally planned economies depressed it[18].

The impact of geography on productivity differences, important in traditional agriculture, appears in the second half of the XX century, especially through aridity. Furthermore, this impact must have been reduced by the extension of irrigated farming for the extreme aridity of the Mediterranean countries, whose high insolation and sufficient water have made them highly competitive and substantial producers and exporters of horticultural products.

This specialisation, already underway in the second half of the XIX century, was also notably consolidated in the XX century (Pinilla and Ayuda, 2010). The intense process of abandoning cultivated land in the mountainous regions of Europe, their specialization in livestock and massive depopulation also explain why the ruggedness variable (referring to the country as a whole and not to cultivated land), despite having the expected sign, is not significant. Lastly, the obstacle for the Scandinavian countries of their extreme climate has not been compensated for by the new agricultural technologies employed, which would partly explain the disappointing performance of such countries in terms of labour productivity.

[18]Obviously, European Union policies also had other effects (e.g. protection or welfare); see Federico (2009).

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Appendix

Countries included in the tables and econometric model:

The econometric model, as an unbalanced panel, includes for each year those countries really existing. These were, until 1990: Albania, the Federal Republic of Germany, the German Democratic Republic, Austria, Belgium-Luxembourg, Bulgaria, Czechoslovakia, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Norway, Netherlands, Poland, Portugal, Romania, Sweden, Switzerland, the United Kingdom and Yugoslavia. From 1990 onward only the German Federal Republic appears, as the consequence of German reunification. From 1991, Yugoslavia has been replaced by Bosnia Herzegovina, Croatia, Slovenia, Macedonia and Serbia-Montenegro. In 1992 Czechoslovakia became Slovakia and the Czech Republic.

We have obtained net production (see later “Calculation of the variables”) since 1950 for all the countries, except Albania which has been included since 1961. All of the countries have been included in the econometric database since 1950, and Albania since 1961.

To calculate the European total, data from all the abovementioned countries were aggregated in the respective years until 1991 and 1992. From 1991, the countries emerging from Yugoslavia have been taken into account. Since 1992, the former Czechoslovakia has been two countries.

Tables 2, 3, 4 and 5 and Figure 1 show that after 1990 the data continue with the previously existing countries, aggregating as a result their successor countries, to maintain the number of units stable. In the case of Germany the opposite is true, aggregating prior to 1990 the data for the two Germanys in a single country. The convergence calculations were performed identically.

Calculation of the variables

Net production: First of all, we downloaded from FAOSTAT (2009) the data for net production in international dollars at 1999-2001 prices. This variable extends from 1961 to 2006. Subsequently, we had to perform certain calculations to obtain the evolution of net production during the 1950s.

To calculate production during the 1950s in the market economies and Yugoslavia, we first used the index numbers from FAO (1948-2004). These FAO index data for gross agricultural production use 1953 and a pre-war level as a base value. Initially, we took as reference the year 1961, assuming that net agricultural production between 1953 and 1961 follows the same trend as this index, which takes 1953 as base. In this way, we obtained net production since 1953. To achieve net production since 1950 we performed the same operation taking 1953 as reference. Thus, we obtain for all these countries an evolution of net agricultural production since 1950.

In FAO (1948-2004) there are no indexes of agricultural production for the Central and Eastern European countries. To achieve a measurement of net production in these countries in the 1950s, we have had to obtain this data differently to the market economies and Yugoslavia. For Hungary and Poland we have used one index of the agricultural production for each country, which appears in Berend and Ranki (1985) and Landau and Tomaszewski (1985), respectively. We have taken as reference net production in 1961 and we have assumed that the evolution of agricultural production in the 1950s follows the trend shown by these indexes. For Bulgaria, Czechoslovakia, the German Democratic Republic and Romania, we obtain production in quantities during the 1950s from FAO (1948-2004). We have calculated production in 1999-2001 dollars using prices from FAOSTAT (2009). Such production has permitted us to obtain an evolution of agricultural production for each country in the 1950s. We have elaborated an index for each country using this variable in this decade. Thus, we have obtained production in the 1950s taking as reference net production in 1961.

Consequently, we have available all production data for all countries since 1950, except Albania (from 1961 onwards only).

Finally, as FAOSTAT does not disaggregate production between the two Germanys until reunification, we calculate it here. For the period 1961-1990 we multiplied 40 products by their respective average prices in 1999-2001, to calculate the gross agricultural production of the Federal Republic of Germany and of the German Democratic Republic. To check the reliability of the calculation, we compared the aggregation with the gross production datum provided by FAOSTAT (2009) for Germany, as if it were a single country, in those years.

Our result ranges from 91% and 99.43% of the FAOSTAT datum, with an average for the entire period of 96.36%. Next, to obtain disaggregated net production, we assumed that the percentage of the gross production of each German republic in their aggregation was identical to their net production. These figures were then applied annually to net production, as provided by FAOSTAT.

Active population: The total active agricultural population was obtained through FAOSTAT (2009) from the estimations made in 2006, dating back to 1961. Subsequently, FAOSTAT published new estimations, made in 2008, but provides the new data only for 1980 onward. The differences between the two estimations are minimal, except for Yugoslavia. This is because for the first year for which the two estimations supply data (1980), the 2006 estimations are only 35% of those of 2008. As a result, for the case of Yugoslavia we take into account the 2008 estimations from 1980 on, and for the data between 1961 and 1979 we use the trend followed by the 2006 estimations, but taking as reference the 1980 datum in the 2008 estimations.

Furthermore, to calculate the total active agricultural population in the Federal Republic of Germany and the German Democratic Republic, the method closely resembles the case of production. The data for Germany, as if it were a single country appearing in FAOSTAT (2009), has been disaggregated taking into account the data for the two Germanys in FAO (1948-2004). We first obtained the relative weight of the active population of each republic as a proportion of the German total in 1960, 1965, 1970, 1975, 1980, 1985 and 1986-1990. The total active population for each of the two countries for those years was used to linearly interpolate between these values to obtain an annual series.

In the case of Romania, we need to reconstruct the active population in agriculture because data prior to 1956 are not available. We assume that the evolution of this variable from 1950 to 1956 has been similar to that of Bulgaria.

Livestock: Live animals are livestock units calculated using the weightings of Hayami and Ruttan (1985).

Fertilisers: The data used are the total consumption of nitrogen, potassium and phosphate fertilisers. The data for Belgium-Luxembourg from 2000 to 2006 were calculated assuming they grew as fast as in the period between 1995 and 1999. For the 1990 calculation of the fertilisers used in the Federal Republic of Germany and the German Democratic Republic, the weight of each of them in the 1989 total was calculated, to apply these weights to aggregate German consumption in 1990. The data for both countries since 1979 were obtained from the FAO (1979-2003) statistics.

Irrigation: The data used are from FAOSTAT (2009). These data are from 1961 to 2006. We have assumed the data before 1961 have not changed.

Water Deficit Factor: Real evapotranspiration is based on rain data and calculated by evaluating a monthly water balance, assuming an average of 150 mm of water storage in all soils. Potential evapotranspiration is the quantity of water which would be lost from a surface completely covered with vegetation if there is sufficient water in the soil at all times (Linneman et al. 1979).

Human capital: The variables are Gross Enrolment Ratios. To calculate both variables (secondary and tertiary), data are supplied by the World Development Indicators (hereafter WDI, 2011) and Mitchell (2007). Data provided by Mitchell (2007) are the following variables: number of pupils in secondary and tertiary education and country population by sex and age groups. To obtain the annual series we must perform the necessary interpolations. The majority of countries have data available in WDI (2011), except for the 1960s (the database does not provide this decade for these variables) which be calculated with the Mitchell data (2007). Nevertheless, there are several calculations necessary for some countries, which were exceptions.

The case of Albania, with its lack of data from 1976 in secondary education and from 1970 onwards in tertiary education has been calculated using annual growth rates between 1976 and 1980 in the first case, and between 1971 and 1975 in the second case, assuming annual growth to be the same.

During the period between 1970 and 1992 it is assumed that Czechoslovakia had a Gross Enrolment Ratio equal to the Czech Republic in secondary education WDI (2011). The data for the previous decade and its evolution come from Mitchell (2007).

The difference in pupils between German reunification in 1991 and the German Federal Republic in 1990 is used as the number of pupils in secondary education in 1990. To obtain the annual series, we then use this figure with the evolution of this variable from Mitchell (2007). The Gross Enrolment Ratio in tertiary education is calculated using the data supplied by Mitchell (2007).

The Yugoslavian calculation uses data from Mitchell (2007) until 1990. The figure for 1991 is the 1990 figure assuming an increase by the annual growth rate of 1986-1990. In Croatia, Bosnia and Serbia it is assumed that they had the same figure for the first year of the sample as Slovenia in 1991 in secondary education and Yugoslavia in 1990 in tertiary education. We then interpolated to obtain the annual sample.

It is assumed that Switzerland evolved similarly to Austria prior to 1978, which is the first year provided for WDI (2011).

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