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Essays on international agricultural productivity in a long term perspective

PhD Dissertation

Miguel Martín-Retortillo Naya

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Universidad de Zaragoza

Applied Economics and Economic History Department

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A María Ángeles Baquer y María Cruz Cabrero, mis dos abuelas.

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Contents

List of Tables

List of Figures

Introducción

Los procesos de desarrollo que se han producido en la economía mundial han supuesto una pérdida de importancia de la agricultura como consecuencia del cambio estructural. A pesar de ello, este sector mantiene un papel muy importante en la economía mundial, principalmente por el gran peso que todavía tiene en la economía de los países en vías de desarrollo.

Asimismo, una población mundial creciente, con problemas de insuficiencia alimentaria en ciertas regiones, otorga mayor importancia al estudio del sector que aporta gran parte de la alimentación humana desde hace siglos. Las estimaciones de FAO predicen una población mundial de más de 9.500 millones de personas a mitad de siglo XXI. Por si fuera poco, el crecimiento poblacional estimado por FAO se concentra hasta 2050 en la población urbana, debido a que la rural se vería mermada en más de 200 millones de personas.

Pero la población mundial en los dos últimos siglos también ha tenido un ritmo de crecimiento sin precedentes, mientras que grandes áreas poblacionales han salido de la pobreza extrema. Estas dos grandes tendencias han podido producirse conjuntamente gracias a un progreso técnico nunca visto en la historia. Este progreso técnico ha conllevado profundas transformaciones en el sector. A lo largo de los últimos siglos, especialmente en el siglo XX, las transformaciones derivadas de este progreso técnico supusieron el paso de una agricultura de base energética orgánica a otra de base inorgánica, así como un mayor uso del factor capital, frente a los factores más empleados en la agricultura tradicional (tierra y trabajo).

Estas preocupaciones y transformaciones han centrado parte de la literatura que ha analizado el sector agrario en la economía mundial (Alston and Pardey 2013), en los procesos de desarrollo económico (Gollin 2010, Lains y Pinilla 2009), en las transformaciones de este sector (Grigg 1992, Federico 2005) y más concretamente en el estudio de la productividad agraria (Gollin et al. 2014a y 2014b).

Una de las principales consecuencias de estas transformaciones es un incremento en la productividad de la agricultura, también sin precedentes. Productividad, no sólo parcial, medida como productividad de la tierra o del

trabajo, sino también de la Productividad Total de los Factores (en adelante, TFP), definida por Coelli et al. (2005: 3), como "productivity measure involving all factors of production". A pesar de la generalización de la mejora de la productividad, se han producido diferencias entre países con respecto a la intensidad de esta mejora. Este es el objetivo de esta tesis: el análisis de las diferencias de productividad en la agricultura desde la Segunda Guerra Mundial hasta la actualidad.

Se trata, por tanto, de una tesis de historia económica, concentrada especialmente en los debates de la historia y la economía agraria y del desarrollo económico. Hay muchos trabajos sobre las diferencias de productividad en la literatura de economía agraria (Sharma et al. 1990, Mundlak et al. 1999, Ball 2001, Coelli and Rao, 2005, Avila y Evenson 2010, Ezcurra et al. 2010, Headey et al. 2010, Ball et al. 2010, Fuglie 2010 y 2012), pero estos estudios carecen de perspectiva histórica, ya que en algunos los horizontes temporales no son muy extensos o cuando lo son no incorporan una interpretación del contexto histórico que acontece en el período tratado. Desde el punto de vista de la historia económica, existe literatura que ha clarificado estas diferencias, aunque no es muy abundante. Libros como el de Federico (2005), Grigg (1992) o Bairoch (1999) y artículos como el de Van Zanden (1990) o O'Brien and Prados de la Escosura (1992) han analizado las diferencias de productividad en la agricultura, observando que estas diferencias se mantienen a pesar del acceso a ciertas innovaciones técnicas.

La tesis doctoral profundizará en el análisis cuantitativo de las diferencias de productividad de la agricultura, pero sin perder el contexto histórico del que en muchas ocasiones carecen los estudios de economía agraria. Para llevar a cabo este análisis de las diferencias de productividad se van a emplear distintas metodologías: las propias de la investigación económica, como los métodos cuantitativos o econométricos, o el estudio del contexto histórico de la economía, especialmente de la agricultura de la segunda mitad del siglo XX. Además, como se ha expuesto con anterioridad, la tesis se concentra en varias mediciones de la productividad, es decir, en el análisis en las diferencias de la productividad del trabajo o de la TFP en la agricultura, así como en explicar las fuentes del crecimiento de la producción agraria.

La explicación de estas diferencias de productividad en la agricultura cuenta con cierta relevancia no sólo en el ámbito de la historia agraria y económica, sino también en el del crecimiento económico moderno. Estas diferencias se ven influenciadas por diversas causas que afectan al crecimiento económico moderno, ya sean causas próximas o fundamentales. Indudablemente, como se ha expuesto anteriormente, el progreso técnico y la adopción de innovaciones han jugado un papel muy relevante a la hora de explicar estas diferencias.

No obstante, las causas fundamentales del crecimiento económico moderno también tienen un papel relevante a la hora de explicar estas diferencias. La geografía se ha utilizado para explicar las diferencias entre los niveles de crecimiento y desarrollo de los países (Sach and Warner 1995, Sachs 2000). Esta causa fundamental influye de manera decisiva en la agricultura a través de variables como la temperatura, la calidad del suelo, las precipitaciones y la disponibilidad de agua o la orografía (Grigg 1982). Las instituciones, que son otra causa fundamental del crecimiento económico moderno (Acemoglu et al. 2001, Acemoglu 2002 and 2005), no tienen un papel menor en la explicación de estas diferencias (Bardhan 1991). La distinción entre los sistemas económicos, como la pertenencia a un sistema de mercado o de planificación central, la política comercial y la agraria, las inversiones en infraestructuras, especialmente las de regadío o los incentivos a la inversión son algunas de las principales líneas de influencia de las instituciones en las diferencias de productividad y de las fuentes del crecimiento del output agrario.

En todo este debate, la tesis pretende responder a las siguientes cuestiones concretas:

- En el contexto posterior a la Segunda Guerra Mundial, ¿qué explica el crecimiento de la producción agraria? ¿se pueden encontrar diferentes patrones de crecimiento dentro del continente europeo? ¿en qué se basa la existencia de estos diferentes patrones?
- En el mismo contexto, ¿a qué se ha debido el mantenimiento de las diferencias de productividad del trabajo agrario cuando las innovaciones tecnológicas del sector fueron adoptadas masivamente por

todos los países? ¿qué papel han jugado las instituciones y la geografía en ello?

- En cuanto a la TFP de la agricultura europea desde 1950, ¿cuál ha sido su tendencia? ¿qué papel han jugado las causas fundamentales del crecimiento económico en la explicación de sus diferentes tendencias? Más concretamente, ¿qué rol han tenido las instituciones y las condiciones medioambientales?
- El panorama en los países latinoamericanos es específico dentro del contexto mundial en cuanto a la relación del sector agrario con el crecimiento económico que se ha producido en los últimos años. ¿A qué se ha debido esta especificidad? ¿cuáles han sido las fuentes del extraordinario crecimiento de su producción en la agricultura? ¿cuáles han sido los principales determinantes de la productividad del trabajo en los países latinoamericanos? ¿qué papel han jugado la productividad de la tierra y el ratio tierra por trabajador? ¿ha existido un patrón general para los países latinoamericanos?

Para contestar a estas preguntas, la tesis se concentra en la segunda mitad del siglo veinte. La tesis consta de cuatro capítulos. Los tres primeros capítulos se concentran en los países del continente europeo con la excepción de la Unión Soviética y los países que después de su disolución se crearon.

En el primero de ellos, se explican las principales tendencias del sistema agrario del continente europeo, concentrándose en la identificación de tres patrones diferentes dentro de este continente. Asimismo, se pretende corroborar el resultado de Federico (2005: 221) que afirma que el crecimiento de la producción de este sector en el siglo XX fue intensivo, es decir, se produjo por incrementos de la productividad. Esta fuente de crecimiento contrasta con el patrón explicativo típico del crecimiento del siglo XIX, que fue un crecimiento extensivo, es decir, por crecimientos de los inputs. Para todo ello, primero, se estima y se analiza la evolución desde 1950 de la producción de la agricultura de los países europeos. A continuación, se observa también la evolución de los factores productivos del sector agrario: la tierra, las hectáreas irrigadas, el ganado, fertilizantes químicos, tractores agrícolas y los activos agrarios. Tras la evolución

de estas variables, se estima la TFP del sector en estos países, teniendo en cuenta las ponderaciones empleadas en Federico (2011: 65)[1].

En el segundo capítulo se pretende explicar las diferencias de la productividad del trabajo agrario en el contexto europeo desde 1950 hasta los años precedentes a la crisis actual, incluyendo causas próximas y fundamentales del crecimiento económico. En él, se incluyen primero un análisis de la productividad del trabajo, así como de las fuentes de su descomposición, la productividad de la tierra y de la ratio tierra por trabajador. A continuación, se analiza la existencia de sigma convergencia, es decir, la evolución de la dispersión entre las diferentes evoluciones de la productividad del trabajo en la agricultura. Después de observar, que estas diferencias se mantienen a lo largo del período, se analizan los determinantes de éstas. Primero, realizando un análisis cuantitativo de los niveles de la productividad del trabajo de la agricultura explicando estas diferencias tanto de variables incluidas en la función de producción, así como por variables que recojan la influencia de las causas fundamentales. Segundo, efectuando un análisis dinámico, en el que la variable a explicar sería el crecimiento de la variable objetivo de este capítulo y como variables explicativas estarían el nivel inicial de ésta variable, así como el de los diferentes inputs y de las variables que miden las causas fundamentales.

El tercer capítulo de esta tesis analiza los determinantes de la TFP agraria de los países europeos. Este análisis de los determinantes se centra, principalmente, en las causas fundamentales del crecimiento económico moderno. Para llevar a cabo este objetivo, primero, se calcula una serie anual de la TFP agraria para los países europeos. A continuación, se plantean dos modelos cuantitativos para observar estas influencias. El primero es de corte transversal, en el que la variable a explicar es la media del crecimiento de la TFP entre 1950 y 2006, siguiendo el tipo de estimación que realizan Headey et al. (2010). El segundo consiste en un análisis de datos de panel con la misma variable a explicar, pero en

[1] La base de datos de la FAO y de FAOSTAT ofrece información para múltiples variables relacionadas con el sector agrario a nivel nacional. Muchas de las variables empleadas en la tesis se han obtenido de esta base de datos. Gollin et al. (2014a) comparan los datos macro de FAO con los de studios microeconómicos, encontrando "a compelling correlation between the two data sources" (Gollin et al 2014a: 169).

serie anual. En ambos modelos, las variables explicativas son diversas variables que miden las distintas causas fundamentales.

El cuarto capítulo, en cambio, focaliza su objetivo en el análisis de la agricultura de los países latinoamericanos. La agricultura en estos países ha sido una fuente de crecimiento económico en las dos últimas décadas. Se pretende explicar en este último capítulo la situación en la que se ha encontrado la región latinoamericana frente a otras del resto de mundo. Así, se llega a la conclusión que su sector agrario ha tenido un crecimiento productivo elevado, al igual que en otras regiones en vías de desarrollo, pero su patrón tecnológico es el que más se acerca al de los países occidentales.

Además, este capítulo explica el crecimiento sin precedentes del output agrario en esta región, que ha sido del 3% anual durante más de 50 años. Para ello, se calcula los incrementos en el uso de los inputs y de la productividad total.

Por último, el formato seguido para la realización de esta tesis es el de la compilación de artículos académicos y por tanto, mantiene el formato de éstos. Los dos primeros capítulos ya han sido publicados en revistas científicas. Además, tres de ellos han sido presentados en congresos y reuniones científicas.

El capítulo 1 ha sido presentado en 9th European Social Science History Conference (Glasgow, Reino Unido), en el Seminario del Departmento de Historia Económica de Lund (Lund, Suecia) y Publish or Perish Workshop (Utrecht, Países Bajos). Este capítulo ha sido publicado en *Agricultural History Review*.

El capítulo 2, publicado en *Cliometrica*, ha sido presentado en Rural History 2010 (Brighton, UK), Seminario de la Sociedad Española de Historia Agraria (Madrid, Spain), Workshop. Investigaciones de Historia Ambiental (Zaragoza, Spain), First Quantitative Agricultural and Natural Resources History Conference (Agricliometrics) (Zaragoza, Spain), 2012 Economic History Society Annual Conference (Oxford, UK) y VII European Historical Economics Society Summer School (Madrid, Spain).

El capítulo 4 se ha presentado en varios foros académicos: Congreso de la Asociación Uruguaya de Historia Económica, Congreso Latinoamericano de

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Introduction

The development processes that have engendered the global economy have involved a decline in the importance of agriculture, as a consequence of structural change. Nevertheless, agriculture remains a crucial factor in the world economy, largely stemming from its central significance in developing countries.

Additionally, a growing world population, with problems of limited food supply in certain regions, underlines the importance to the study of the sector which supplies great part of human food for centuries. The UN's Food and Agriculture Organization (FAO) predicts a world population in excess of 9.5 billion by the second half of the 21st century. To make matters worse, the bulk of this growth is estimated by the FAO to be concentrated in urban populations, with a concomitant decline of 200 million in rural areas.

In the last two hundred years, the population of the planet has grown explosively and substantial numbers of people have emerged from extreme poverty, thanks, primarily, to unprecedented technical change that accelerated into – and through – the 20th century. Broadly speaking, agriculture transitioned from an organic base to an inorganic base, with expanded utilisation of capital inputs, moving away from the traditional factors of land and labour.

These concerns and transformations have been addressed in the literature, which has analyzed the agricultural sector in terms of the global economy (Alston and Pardey 2013), of the processes of economic development (Lains and Pinilla 2009, Gollin 2010), of the transformations within the sector (Grigg 1992, Federico 2005) and, more concretely, in terms of agricultural productivity (Gollin et al. 2014a and 2014b).

One of the major consequences of these transformations has been a historic increase in agricultural productivity, not simply in terms of labour and land, but also of the Total Factor Productivity (TFP, henceforth), defined by Coelli et al. (2005: 3) as "a productivity measure involving all factors of production". Despite the generalization of increasing productivity, cross-country analyses have identified significant differences in the intensity this evolution. This brings us to the objective of this thesis: the analysis of the variations in agricultural

productivity from country to country, from the Second World War to the beginning of the 21st century.

This, then, is about economic history, focusing especially on the debates in agricultural history, economics, and the phenomenon of economic development. Much work has been done examining the differences in agricultural productivity (Sharma et al. 1990, Mundlak et al. 1999, Ball 2001, Coelli and Rao, 2005, Dias Avila and Evenson 2010, Ezcurra et al. 2010, Headey et al. 2010, Ball et al. 2010, Fuglie 2010 and 2012), but these studies lack historical perspective – in some cases because the sample periods are short, in others because the studies do not include an interpretation of the historical context. From the point of view of economic history, there are some few works that have clarified these differences; books by Federico (2005), Grigg (1992) and Bairoch (1999), and papers from Van Zanden (1990) and O'Brien and Prados de la Escosura (1992), have analysed the differences in agricultural productivity, observing that these differences have persisted, despite access to certain technical innovations.

In this dissertation, the quantitative analysis of differences in agricultural productivity is expanded by taking into account the historical context that is often lacking in studies of agricultural economics. To carry out this analysis of productivity differences, we use different methodologies: the economics methodology (quantitative and/or econometric methods), and an approach to the study of the economy in its historical context, especially of the agriculture of second half of the 20th century. We focus on a range of measurements of productivity, through an analysis of agricultural labour productivity and of agricultural TFP, and we attempt to identify the sources of agricultural production growth. As we have seen, technical progress and the adoption of innovations have both played an important role in explaining these differences in levels of productivity.

However, the fundamental causes of economic growth are equally important in explaining these differences in productivity. Geography has been used to explain the distinct levels of growth and development among countries (Sachs and Warner 1995, Sachs 2000), examining variables such as temperature, soil quality, rainfall and the availability of water, or orography (Grigg 1982).

Institutions are another fundamental factor in economic growth (Acemoglu et al. 2001, Acemoglu 2002 and 2005, Bardhan 1991). The distinctions among economic systems, such as the membership of a market or a planned economic system, the commercial and agricultural policy, infrastructure investments, especially in irrigation, and the incentives for investment, are all sources of differences in agricultural output growth.

In this debate, we aim to address these specific questions:

- In the post-Second World War context, what explains agricultural production growth? Is it possible to identify differential patterns of growth on the European continent? From what sources did these patterns emerge?
- In the same context, what explains the maintenance of differences in agricultural labour productivity when the technological innovations were adopted massively by all the countries? What roles have institutions and geography played?
- What has been the trend in agricultural TFP in Europe since 1950? What roles have the fundamental causes of economic growth played in the explanation of these trends? More specifically, how have these trends been influenced by institutions and geography?
- The Latin American experience is specific in terms of the relationship of the agricultural sector to economic growth that it has produced in the last years, but what does this specificity explain? What have been the sources of this extraordinary agricultural output growth? What have been the primary determinants of labour productivity in these countries? What roles have land productivity and land-labour ratios played? Is it possible to identify a general pattern for Latin American countries?

The thesis has four chapters. The first three chapters focus on the European continent (with the exception of the USSR and the countries that emerged after its dissolution).

Chapter 1 explains the main trends of European agricultural systems, focusing on the identification of three different patterns. Additionally, it seeks to corroborate Federico's result (2005: 221), pointing out that growth in agricultural output in this period was intensive, resulting from productivity increments. This source of growth contrasts with the extensive growth of the 19th century, which resulted from input increments. The chapter begins with an estimation and analysis of the evolution of agricultural production since 1950 of European countries, and continues with the evolution of agricultural inputs: land, irrigated hectares, livestock units, chemical fertilizers, agricultural machinery, and workforce. Following this is an estimation of TFP in these countries, following the weightings used by Federico (2011: 65)[2].

Chapter 2 explains the differences in agricultural labour productivity in Europe from 1950 to the years immediately prior to the current crisis, including the proximate and fundamental factors underlying economic growth. The chapter includes an analysis of the evolution of labour productivity, as well as of the sources of its decomposition, land productivity and the land-labour ratio. An analysis of sigma-convergence follows, i.e. the evolution of dispersion among the distinct iterations of labour productivity, and we examine the determinants of those differences. First, there is a quantitative analysis of levels of agricultural labour productivity, followed by a dynamic analysis in which the explanatory variables are used to measure fundamental causes.

Chapter 3 analyzes the determinants of agricultural TFP in European countries, primarily focused on the fundamental stimulants of modern economic growth. First, we calculate the annual series of agricultural TFP for the countries under analysis, and propose two quantitative models to observe these influences. The first is a cross-section analysis, in which the explanatory variable is the average of TFP growth between 1950 and 2006, following the lead established by Headey et al. (2010). The second is a panel data analysis with the same

[2] FAO and FAOSTAT's database offers information of multiple variables related with the agricultural sector at national level. A lot of the variables used in this dissertation are from this database. Gollin et al. (2014a) compare the macro data from FAO database with the data from micro-studies, obtaining "a compelling correlation between the two data sources" (Gollin et al 2014a: 4).

explanatory variable, but as an annual series. In both models, the variables measure distinct fundamental causes.

Chapter 4 focuses on a comparative analysis of the agriculture of Latin American countries, which has been an engine of growth for two decades, concluding that the sector enjoyed high productive growth, as in other developing regions, but its technological development is closer to that of the more developed countries. The growth of agricultural output in Latin America, at an annual rate of 3% for more than fifty years, is unprecedented, and we calculate the increments in the use of inputs and in the Total Factor Productivity.

The format followed for the completion of this dissertation is the compilation of academic articles. This dissertation maintains the format of these; two chapters have been published in scientific journals, and three have been presented at conferences and scientific meetings.

Chapter 1 was presented at the 9th European Social Science History Conference (Glasgow, UK), the Seminar of the Economic History Department (Lund, Sweden), and the Publish or Perish Workshop (Utrecht, The Netherlands). This chapter was also published in *Agricultural History Review*.

Chapter 2, published in *Cliometrica*, was presented at Rural History 2010 (Brighton, UK), Seminario de la Sociedad Española de Historia Agraria (Madrid, Spain), the Workshop in Investigaciones de Historia Ambiental (Zaragoza, Spain), the First Quantitative Agricultural and Natural Resources History Conference (Agricliometrics) (Zaragoza, Spain), the 2012 Economic History Society Annual Conference (Oxford, UK), and the VII European Historical Economics Society Summer School (Madrid, Spain).

Chapter 4 was presented at the Congreso de la Asociación Uruguaya de Historia Económica, the Congreso Latinoamericano de Historia Económica (CLADHE IV), the 17th Summer School on the History of Economic Thought, Economic Philosophy and Economic History, the International Congress of the Spanish Association of Economic History (Madrid, Spain), and at the Seminar of the Economic History of Universidad Carlos III de Madrid.

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Chapter 1. Patterns and causes of the growth of European agricultural production, 1950-2005

In recent decades the changes in the agricultural sector has undergone have permitted it to increase production rapidly, replacing the productive factors most commonly used in traditional agriculture (land and labour) by capital; it has in addition made increasing use of new technologies.

This intensive process of agricultural transformation in the developed countries (and also that experienced later by developing countries) has been the subject of close attention by researchers. Many authors, such as Federico (2005 and 2011), Hayami and Ruttan (1985), Mundlak (2000), Gardner and Rausser (2001 and 2002), Evenson and Pinghali (2007 and 2009) or Grigg (1982 and 1992) have contributed to an improved understanding of the modernisation of agriculture, from both the theoretical and empirical viewpoint.

In the opinion of the present authors, such literature nevertheless lacks studies which concentrate, from a long-term perspective, on the transformations which have taken place since the Second World War on the European continent, and which include both the Western countries and those which belonged for many years to the Communist bloc.

The analysis of European agriculture in the decades prior to 1945 or the years immediately following has generated significant interest on the part of researchers, with both comparative studies of various European countries and others which perform diverse national case studies (Yates 1960, Dovring 1965, Tracy 1989, Van Zanden 1991, O'Brien and Prados 1992, Lains and Pinilla 2009, Olsson and Svensson 2011).

Against this background, our objective is to determine the principal causes of agricultural growth, that is to say the relative contribution of inputs and total factor productivity (TFP) on the European continent between the Second World War and the beginning of the twenty-first century. Our effort is part of an attempt, for a significant part of European economic history, to extend the analysis of the evolution of the different national cases by using comparative perspectives which include a considerable number of countries[3]. Moreover several previous studies of

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

agricultural economics have estimated and analysed the growth of TFP in European agriculture for shorter time periods (Wong and Ruttan 1990, Thirtle and Bottomley 1992, Ball et al. 2010, Fuglie 2008, 2010 and 2012).

We wish to verify whether Europe fulfils the hypothesis of Federico, namely that agricultural growth in this period has been intensive (Federico 2005: 221). That is to say, it has been based above all on the increase in TFP, as against the model of extensive growth, based on the increase in inputs, which was characteristic of the XIX century. Yet we intend to go further and attempt to see whether the patterns of agricultural growth were common for the European continent or whether differentiated models can be established.

To achieve the objective proposed we need to calculate the relative contributions made to the growth of agricultural output between 1950 and 2005 by the increase in inputs and by total factor productivity. This requires the previous reconstruction for this time horizon of the series of variables necessary: inputs (labour, land and capital) and output. Part of these data can be obtained directly from the FAOSTAT databases[4]. In some cases it has been necessary to perform additional estimations and calculations. These estimates have been especially important for the 1950s, for countries with centrally planned economies and for Germany until its unification process. The procedure we have used to estimate TFP is that termed the Solow residual, and in particular the methodology of "growth accounting", which in turn takes into account the possibility that the relative intensity of factor use varies over the study period.

The European continent has certain characteristics which justify our selection and underline its interest. Firstly, we believe it is important that some of the countries which comprise it were pioneers in the industrial revolution, and thus by 1950 had travelled a long way along the path of economic development. Others, by contrast, had been left behind. Additionally, the institutional divergence caused by the division of the continent into two political and economic blocs from

[4] The data for agricultural production in FAOSTAT was in constant prices. FAOSTAT, FAO Database. (2009). One recent paper 'find essentially no disagreement between the FAO yield data and the many micro estimates of grain yields' Gollin et al. (2014: 169).

1945 onwards permits us to contrast the importance of institutional factors in the processes of economic growth.

The period on which we shall concentrate, that subsequent to the Second World War, is of great importance. In the agricultural sector, there took place the substantial use of agricultural machinery, chemical fertilizers, pesticides and herbicides, the development of intensive livestock breeding, improved breeds of animals, better access to agricultural credit, the genetic selection of seeds and the expansion of irrigated farming (Grigg 1992, Gardner 1996, Evenson and Gollin 2003, Federico 2005, Mazoyer and Roudart 2006, Josling 2009). Furthermore, from the institutional point of view this is a historic period in which the continent was reconstructed following World War Two. The European Economic Community, the future European Union, was created and subsequently expanded. Finally, various Central and Eastern European countries remained under a Communist regime for over forty years in this period, their transition towards a market economy taking place only subsequently.

Our results show that the rapid growth of agricultural output which took place in European countries differed greatly according to countries. Three different models of agricultural growth can be identified. That of the Western European countries (those most developed in 1950) was principally based on a rapid growth of TFP throughout the entire period. The increase in the use of capital also played a very important role. This was especially important in the decade of the 1950s, tending to decrease from then on.

The opposite model is that of the Central and Eastern European countries, which had planned economies until the early 1990s. Heavy capital investment was crucial in these countries to achieve agricultural growth, while the contribution of TFP was small. Finally, the Mediterranean and Nordic countries are located in an intermediate position. The contributions of capital were higher than in the Western European countries but clearly lower than in the Central and Eastern European countries. In all cases, the fall in land use and, above all, workers, was very significant.

To achieve the objective proposed, the present article adopts the following structure. Firstly, we analyse the evolution of agricultural production. Next, we examine the patterns and intensity of the use of productive factors. Subsequently, we analyse the causes of the growth of output: technical progress and the increase in TFP. The study ends with a conclusions section.

II

This section is aimed at clarifying the different trends in agricultural production among the European countries. Table 1.1 shows that European agricultural production increased sharply from 1950 until the mid-1980s, from when on it stagnated. The evolution of production can be analysed in greater detail. Post-war recovery was rapid (Federico 2012); despite the serious distortions and destruction caused by the war, by 1950 the pre-war level of production had not only been regained but also exceeded. In general, the greater the involvement of a country in the conflict, the smaller was the increase in its production. Two cases are notable for their slow recovery. The first is that of the German Federal Republic, which by 1950 had not yet recovered its pre-war level. This country contrasts with the UK and Switzerland, less affected by the war, in which production was 22 and 9 per cent higher respectively, comparing the pre-war level to 1950. The second is Spain, which did not participate directly in the conflict and had ended its civil war in 1939; it was gravely affected by the subsequent policies of the Franco dictatorship and the international isolation of the country (Clar and Pinilla 2009).

Following the recovery immediately subsequent to World War Two, a further sharp increase in production took place in the 1950s. In the market economies the annual growth of production was 3.07 per cent between 1950 and 1962. In those years there was great institutional preoccupation with resolving the food shortages of the war and subsequent years (Glynn and Booth 1996, Dormois 2004). The agricultural sector was also considered to have a strategic role to play in the economy. In addition, the sector employed a great number of workers in those years (Andreosso-O'Callaghan 2003). Encouragement was given to improve

access to agricultural credit and favour in this way the capitalisation of the sector (Nodstrom 2000). For example, France, although it was not an isolated case, dedicated part of its resources from the Marshall Plan to distributing fertilizers and mechanical equipment (Zamagni 1993, Dormois 2004, Jespersen 2004, Josling 2009, Bieleman 2010).

Table 1. 1. Net production (millions of $US) (1999-2001 prices)

	Pre-war	1950	1962	1972	1982	1992	2000	2005
Western Europe	30,763	32,945	47,292	56,190	67,629	73,194	73,329	71,238
Mediterranean E.	23,225	22,797	31,912	38,515	46,586	51,011	54,755	54,144
Nordic Europe	3,604	4,015	4,465	4,478	5,192	4,717	4,848	4,903
Central & Eastern E.	n.a.	20,059	28,074	36,220	43,109	39,311	36,118	38,031
GFR/Germany	8,846	8,050	13,764	15,540	18,350	24,906	26,342	25,443
GDR	n.a.	3,971	4,206	5,787	6,777	-	-	-
France	14,038	14,272	22,538	26,754	30,588	31,894	33,071	32,425
United Kingdom	5,929	7,213	9,211	10,957	13,411	14,348	13,425	13,075
Italy	12,086	12,610	16,976	19,972	23,782	23,881	23,981	23,663
Spain	7,253	6,214	9,296	12,069	15,128	18,080	21,241	21,482
Poland	n.a.	7,053	9,956	11,934	12,755	13,136	12,386	13,138
European market economies	66,438	67,807	97,433	114,723	137,758	153,828	159,273	155,728
Europe	n.a.	94,412	129,713	156,730	187,643	193,139	195,392	193,760

The data presented, except the pre-war level, are triennial averages based on the benchmark year. The data for 1950 are the average between 1950 and 1951 for the GDR, Central & Eastern Europe, Poland and Europe. The GFR/Germany row displays data from the Federal Republic of Germany until 1992; from that year on the data are for the reunified Germany. See the Appendix for the composition of the groups and the definition of the pre-war level.
Source: Authors' compilation, using data from *FAO production yearbook*, 1948-1976, *FAO production yearbook*, 1977-1986; *FAO production yearbook.*, 1987-2004, Rome; FAOSTAT, *FAO Database.faostat.fao.org.* (2009), Accessed June 2009 and April 2010. For details, see the Appendix.

In general, the Western European countries implemented policies of support for their agricultural sectors; these increased state intervention in the sector and stimulated production. In imitation of the state intervention in agriculture initiated in the United States during the Great Depression, and continuing the policies of the control of production and consumption developed during World War Two, the Western European countries maintained the absence of a free market in the agricultural sector (Federico 2012). Agricultural policy explicitly sought self-sufficiency in food and an increase in agricultural productivity in the European countries (Landau and Tomaszewski 1985, Lampe 1986, Fennell 1997, García Delgado and García Grande 2005, Neal 2007). In this context, the European

Economic Community was formed in 1957and the Common Agricultural Policy (henceforth CAP) established in 1962. This meant no radical break with the previous policies of the member states, but instead a homogenisation and convergence among them. The objectives for the agricultural sector contained in the Treaty of Rome were the increase of productivity, the guarantee of reasonable prices for consumers, the achievement of an equitable standard of living for farmers, market stability and guaranteed supply. The development of this treaty, through the CAP, left its mark on the agricultural sector for decades, especially until 1992 and the MacSharry reform.

During the first decades of its existence the CAP fixed high prices for a substantial part of agricultural production, normally taking as reference the highest price for each product from among the founding countries. This policy of high prices, generally much higher than those in the international market, stimulated an increase in production. The natural result of this policy was also that agriculture in the European Economic Community needed strong commercial protection (Tracy 1989, Gardner 1996, Andreosso-O'Callaghan 2003, Neal 2007).

The result of guaranteed high prices, strong protection and the close and deep integration of markets among the member states was a considerable increase in production and productivity, the relatively quick achievement of self-sufficiency in food and a sudden change in the European position in international markets for agricultural products[5].The new technological supply made it easier for these policies to stimulate a strong increase in production. Agricultural trade among the member countries increased considerably, while there was a significant fall in their participation in international markets as importers (Pinilla and Serrano 2009, Serrano and Pinilla 2011).

Furthermore, certain countries displayed spectacular growth in that decade. Thus, in the United Kingdom, in the period between the Second World War and the mid-1960s there took place the greatest growth in agricultural output since the

[5] In various products, this self-sufficiency was achieved relatively rapidly by the end of the 1950s in the countries forming the European Economic Community, but especially in the 1960s and 1970s (Tracy 1989, Fennell 1997). For the change in the European position in world agricultural markets, see Aparicio et al. (2009).

1870s (Brassley 2000). Another notable case is that of the Federal Republic of Germany, whose production rose by almost 4 per cent annually; the 1950s and 1960s have been described as an "economic miracle" (Wilson and Wilson 2001).

In the countries of the Communist bloc the change in agricultural structures was total, as the consequence of the implantation of the Soviet model. Planning also boosted production, specifically at an annual growth rate of 2.84 per cent in the 1950s[6]. Despite this impulse, there was a continuance of the distortions which began with the institutional changes following the war, due to the processes of collectivisation and price and salary regulation (Berend and Ranki 1985, Landau and Tomaszewski 1985, Lampe 1986, Pryor 1992, Anderson and Swinnen 2009).

The growth of production continued in the 1960s and 1970s. In the market economies there was some slowing down of the sharp increase in output of the previous decade, which nevertheless grew by 1.65 per cent annually between 1962 and 1972 and by 1.85 per cent in the following decade. The country with the fastest growth was Spain, expanding by 2.46 per cent between 1962 and 1982. This may be explained by the opening of the Spanish economy due to the Stabilisation and Liberalisation Plan in 1959, which produced generalized economic growth and the massive incorporation of Western technology (Reig and Picazo 2002, Prados de la Escosura et al. 2011). Another notable case is that of the countries of the Communist bloc, with a rapid annual growth of 2.16 per cent in the 1960s and 1970s, although with many differences among them (Gregory and Stuart 2001). There were frequent increases in livestock products and a change from traditional cultivated products towards fruit and vegetables and vines (Landau and Tomaszewski 1985, Berend and Ranki 1985, Lampe 1986).

The 1980s mark a point of inflection, as the growth in output slowed down; in the continent as a whole this increased at an annual rate of only 0.29 per cent. This result is strongly biased by the problems of agriculture in the countries of the Communist bloc, since in market economy countries growth continued, although at a slower pace than in previous decades. In the countries belonging to the Communist bloc the transition crisis affected their economies as a whole, while

[6] The GDR was an exception to this growth, as its annual increase amounted to only 0.48 per cent.

agriculture gradually accumulated problems[7]. Throughout this decade agricultural output fell at an annual rate of 0.92 per cent.

Problems arose due to the gap caused by the high prices paid to producers and the low prices demanded by consumers; this gap was covered by direct subsidies. In all these countries the growth in livestock produced distortions, because heavy subsidies were required, as were massive imports of cereal to meet the needs of livestock feeding[8]. Trade protection in these countries came to mean equivalent welfare losses of between 50 and 75 per cent of the benefits of direct subsidies to consumers (Gray 1990, Anderson and Swinnen 2009). In the German Democratic Republic large collective farms were heavily indebted, due to their inefficiency (Forstner and Isermeyer 2000).

The evolution of agricultural output during the 1990s was very different in the market economies and in the Communist bloc, the latter in the midst of dissolution and a transition towards market economies. On the one hand, the free market countries continued to display very slow growth during most of the decade. An essential change took place in 1992 with the MacSharry reform of the CAP. This meant a shift from a pricing policy to one of direct income support. Despite this change, a considerable part of Mediterranean products, such as olives and vines, were not included in this legislative reform (García Grande 2005, Neal 2007). It was also at the beginning of the 1990s that the inclusion of agriculture in the Uruguay Round of the General Agreement on Tariffs and Trade (henceforth GATT) meant the start of a liberalisation process in international markets, which

[7]An example of these tensions occurred in the Soviet Union, which was in great need of imported cereals. Due to oil and gas exports there was no problem in financing cereal imports until the mid-1980s, when the prices of energy products fell, harming the financing of these massive imports (Gray 1990, Anderson and Swinnen 2009).

[8] Thanks to this boost to the output of livestock activities, per capita consumption of these products increased (and doubled in the USSR between 1950 and 1980), outstripping that of the OECD countries, despite the standard of living being lower (Anderson and Swinnen 2009, Diamond et al. 1983).

affected the European position[9]. This trend was reinforced with the further reform in 2003 of the CAP and the increasing concern for the environment[10].

Elsewhere, the countries of the Communist bloc embarked upon their transition to market economies at the beginning of the 1990s. This transition involved serious problems for their economies and, therefore, for their agriculture[11]. There exist differences among countries in the way this transition was performed, and also its effects upon production. It was a stage in which the ex-communist countries had to undertake important institutional reforms, such as price and trade liberalisation, reforms of the land market and the restructuring of farms, added to extreme meteorological conditions in certain years (Macours and Swinnen 2000 and 2002, Anderson and Swinnen 2008). The differences in the transition paths could be illustrated by the Hungarian and Romanian cases. In the former, agricultural output, labour, fertilisers and machinery decreased sharply, while in the latter there were increases in crop output, agricultural labour and the use of machinery (Macours and Swinnen 2000).

From 2000 on, and for the first time since the problematic years of the war, European production fell at an annual growth of 0.17 per cent. Evolution in the first quinquennium of the twenty-first century has not been exactly the same in all regions. The best results have taken place in the ex-communist countries, whose production increased by an annual rate of 1.04 per cent, recovering part of what had been lost in preceding decades. This was due to the progressive overcoming of the institutional problems derived from the transition which they underwent in the 1990s, and also to the implementation of policies aimed at incorporation into the European Union.

[9]European agricultural protection was a constant theme within the GATT and WTO rounds, from Kennedy to Doha (Spoerer 2010).

[10]Animal and plant health, the creation of a network of nature protection, green services provided by agriculture, EU structural and agricultural policies are some questions developed recently in the 1990s and, above all, in the 2000s (Oskam et al. 2010).

[11]The problems of the transition from one economic system to another were, among others, the loss of the traditional international markets of COMECON, the monopoly of distributors (which contributed to increasing the difference between prices received by the producer and retail prices), the decrease in disposable income and the reduction of subsidies to the sector, the increase in productive factor prices at worldwide level, a greater uncertainty provoked by the restructuring of the land market, a lack of experience in private management or a shortage of credit (Trzeciak-Duval 1999).

III

The different trends in the use of inputs are essential to understand the sharp increase in production, as has been seen previously. Throughout the nineteenth century, and also in some countries in the earliest decades of the twentieth century, an increase in the use of traditional inputs, land and labour, had been the principal motor of the growth of agricultural production (Federico 2005: 221). However, after 1950 this tendency changed radically in Europe. Thus, there was a fall in absolute terms in the use of productive factors which predominated in traditional agriculture as opposed to capital, the importance of which increased considerably. This capitalisation took place principally as a consequence of an increase in agricultural machinery and chemical fertilisers.

Table 1. 2. Arable land and permanent crops (thousands of hectares)

	1950	1962	1972	1982	1992	2000	2005
Western Europe	37,134	37,239	33,726	33,263	33,017	32,611	32,847
Mediterranean Eur.	43,470	43,140	40,433	39,953	38,492	35,704	33,725
Nordic Europe	7,046	6,976	6,357	6,123	5,956	5,791	5,786
Central & Eastern Europe	49,680	50,978	49,801	48,528	47,104	45,181	42,294
GFR/Germany	8,552	8,466	7,591	7,465	11,809	12,026	12,089
GDR	5,106	5,055	4,842	5,006	-	-	-
France	21,187	21,322	18,674	18,989	19,297	19,561	19,608
United Kingdom	7,428	7,348	7,203	6,979	6,468	5,866	5,928
Italy	16,612	15,531	12,316	12,369	11,620	11,281	10,261
Spain	19,835	20,800	21,110	20,494	19,898	18,225	17,793
Poland	16,223	16,072	15,177	14,826	14,694	14,218	12,741
Europe	150,987	151,854	142,750	140,337	136,378	131,313	126,741

Triennial average data based on the benchmark year, except 1950. This table does not include grasslands because of the difficulties in obtaining the data for grasslands for the whole sample in the 1950s.
Source: The same as Table 1.1. For details, see the Appendix.

The first input to be analysed is land. Since 1960 there has taken place a reduction in the number of hectares employed as arable land in European agriculture, with the agricultural land area decreasing from almost 152 million hectares to 127 million hectares. This reduction may be due to various factors. On the one hand, the abandonment of farms produced by the structural change in the

economy throughout the entire period was significant. Furthermore, the increase in the average size of farms and in the productivity of land more easily permitted the achievement of economies of scale and, with a lower quantity of land input, an increase or maintenance of production. On the other hand, there took place an increase in the importance of livestock products in total production in the initial decades of the second half of the twentieth century, while the increase in intensive livestock breeding permitted the separation of a part of production from the land factor, especially in countries with less favourable environmental conditions, such as aridity, which traditionally had caused limitations when producing biomass for livestock feed (González de Molina 2001)[12]. Furthermore, in many parts of Europe, the reduction in the cultivated land area was closely linked to the massive rural exodus which took place and which involved the abandonment of many farms, especially those least economically viable (Collantes and Pinilla 2011). This was the case of mountainous zones, where the reduction in the cultivated land area was especially notable (Collantes 2006).

The cultivated land area increased very slightly, at an annual rate of 0.08 per cent, between 1950 and 1962. In fact, this increase only took place in the Central and Eastern European countries. In that decade these countries completed their processes of agricultural reform, and therefore the consolidation of farms (Landau and Tomaszewski 1985, Berend and Ranki 1985, Lampe 1986, Pryor 1992). From then on, the decrease in the number of cultivated hectares was generalized and constant in the last four decades of the twentieth century.

In some cases, such as France, the fall was occasionally more abrupt. An example is the 1960s, when arable land fell by exactly 1.3 per cent annually. This was due to voluntary policies for the consolidation of farms and the payment of supplementary retirement pensions to old-aged farmers (Bouchet et al. 1989)[13]. Following this considerable decrease, a slight increase took place until 2005, although this time it did not recover the level of the early 1960s.

[12] Spain was an exception until the 1980s, since it increased its cultivated land area. This was linked to the great increase in its livestock (Clar 2013).

[13] A similar case occurred in Finland during the 1970s and 1980s, especially with dairy farmers reducing their herds between 1965 and 1989 by two thirds (Singleton 1989).

In contrast to land, capital had a different trajectory in this period of analysis. In the developed countries, the greater use of capital in agriculture has been highlighted as one of its most important features throughout the twentieth century (Federico 2005).

Table 1. 3 Hectares of land equipped for irrigation (thousands)

	1950	1962	1972	1982	1992	2000	2005
Western Europe.	952	1,009	1,548	2,564	3,373	3,957	3,904
Mediterranean E.	5,858	6,779	7,762	8,389	9,223	9,674	10,001
Nordic Europe	40	43	101	213	290	363	371
Central and Eastern E.	1,487	1,796	3,344	4,822	5,481	4,763	4,405
GFR/Germany	270	270	292	316	483	485	485
GDR	124	124	137	165	-	-	-
France	504	532	906	1,460	2,256	2,651	2,675
UK	93	106	86	150	132	243	212
Italy	3,400	3,400	3,400	3,435	3,718	3,844	3,969
Spain	1,341	2,025	2,690	3,105	3,415	3,719	3,834
Poland	200	200	345	340	261	89	118
Europe	8,731	10,021	13,184	16,470	18,849	19,243	19,166

Triennial average data based on the benchmark year, except 1950.
Source: The same as Table 1.1. For details, see the Appendix.

In the more arid European zones or those with greatest difficulty in making sufficient water available for the cultivation of certain crops, an extraordinary effort was made in this period to increase the irrigated land area or to improve the quality of irrigation. Between 1950 and 2005 the area equipped for irrigation grew in Europe by 1.45 per cent annually (Table 1.3), although the distribution of this increase was enormously unequal throughout the continent. In some countries of the Central and Eastern European countries, governments made a huge effort to increase irrigated land (Lampe 1986). Countries such as Romania, Greece and France increased their irrigated land area at an annual growth rate of 5.1 per cent, 3.3 per cent and 3.1 per cent respectively. Also notable are the cases of Spain and Italy, which, although having lower rates of growth, in 1961 possessed 10 per cent and 17.9 per cent of the total European land area equipped for irrigation, as a consequence of the policies of the first half of the twentieth century. For these Mediterranean countries, the increase in irrigated land, faster in Spain that at any

previous time, was crucial for the growth of their agricultural production (Duarte et al. 2014).

Table 1. 4. Livestock units (thousands of units)

	1950	1962	1972	1982	1992	2000	2005
Western Europe	47,383	58,456	63,247	66,921	67,767	67,141	63,142
Mediterranean Eur.	23,383	26,350	25,605	27,102	28,181	28,949	29,229
Nordic Europe	6,638	6,226	5,208	5,325	4,683	4,444	4,263
Central & Eastern E.	37,190	43,004	46,311	50,329	40,356	28,977	27,933
GFR/Germany	13,067	15,347	16,520	17,863	21,550	18,930	17,664
GDR	4,658	6,362	6,976	7,913	-	-	-
France	18,019	22,462	23,319	25,115	23,327	23,727	22,319
United Kingdom	11,654	15,024	16,913	15,757	17,002	16,219	15,123
Italy	11,235	11,502	11,480	11,629	11,229	9,960	9,568
Spain	7,888	9,164	8,778	9,828	11,855	13,826	14,560
Poland	10,495	13,954	16,391	15,712	12,479	9,562	9,883
Europe	131,584	155,744	163,866	175,453	162,536	148,442	142,230

Triennial average data based on the benchmark year, except 1950. Livestock units are the number of animals aggregated with the weightings of Hayami and Ruttan (1985). Consult the Appendix to see which animal species have been taken into account in the calculation of the variable.
Source: The same as Table 1.1. For details, see the Appendix.

Livestock is a very important part of the capital employed in agriculture, because it produces certain consumer goods such as meat, milk, eggs or wool, and it has been employed as the motor of agricultural production. Thus, Table 1.4, which displays the evolution of the number of livestock units, is the result of two opposing trends. On the one hand the decrease throughout the second half of the twentieth century in the number of working animals. On the other, the increasing importance of livestock for the production of meat or milk, especially in countries in which it had been relatively unimportant, as a consequence of their inadequate environmental/ecological conditions. The result was that until the early 1980s there took place a notable increase in livestock numbers in Europe, visible in all its regions with the exception of the Nordic countries.

Consequently, in Europe in general livestock tended to gain importance in agricultural production as a whole until the early 1980s. This improvement in its participation was much more important in those regions where the initial share

was smaller, such as the Mediterranean countries or those of Central and Eastern Europe.

From the beginning of the 1980s there took place an appreciable reduction in livestock numbers. Some of its production was affected in Western Europe by serious problems of oversupply and the change of philosophy in the CAP, with a greater environmental concern for the control of intensive livestock breeding (Gardner 1996, Andreosso-O'Callaghan 2003, García Grande 2005, Anderson and Swinnen 2009). The introduction of milk quotas in 1984 also played an important role in this reduction.

The principal exception to livestock decrease in the market economies was the continued increase after 1980 of livestock numbers in the area least specialized in this activity, the Mediterranean countries. Thus, in Spain, livestock breeding continued to increase until it almost doubled its units, principally due to the enormous growth of intensive livestock breeding processes (Domínguez 2001). This was due in part to the possibilities offered by such processes; they permitted the alleviation of environmental obstacles traditionally faced by livestock (Pinilla and Clar 2011).

On the other hand, it is necessary to underline the significant reduction, by almost 50 per cent in a decade, of livestock numbers which the countries of Central and Eastern Europe experienced from the mid-1980s on. The differences which existed in this system between the low prices paid by the consumer and the high prices paid to the producers, which were covered by direct subsidies, brought about a livestock boom, unsustainable once this policy had ended, in the final decades of Communism.

Lastly, within the capital utilized, there was a considerable increase in the purchase of inputs from other sectors of the economy in European agriculture. From an agriculture which basically used inputs from agriculture itself, there was a change to another in which purchases from other sectors of the economy were dominant. Principally, these were the purchase of machinery, fertilisers, pesticides, seeds, fuel or services from other non-agricultural companies.

Table 1.5 shows the evolution of the consumption of chemical fertilisers per hectare. From 1950 until the 1980s there was a very sharp increase in the use of fertilisers in European agriculture. Although growth was generalized, the Western and Nordic countries already had by 1950 much higher levels than the Mediterranean and Central and Eastern countries, as the former had already introduced this innovation to a greater extent prior to the Second World War[14]. Thus, the greatest increase in the consumption of fertilisers per hectare occurred in the countries of Central and Eastern Europe (10.8% annually), which in 1950 had had the lowest level in the entire continent, while in the Western countries the figure was 4.4%.

Table 1. 5. Kilograms of chemical fertilisers consumed per hectare

	1950	1962	1972	1982	1992	2000	2005
Western Europe	83	164	299	333	287	253	234
Mediterranean Europe	20	45	86	109	118	127	113
Nordic Europe	67	103	199	202	144	133	138
Central and Eastern E.	8	49	154	213	67	77	118
GFR/Germany	161	295	427	425	240	233	211
GDR	159	202	340	305	-	-	-
France	49	124	287	298	254	223	186
United Kingdom	111	195	257	356	322	320	282
Italy	29	56	119	165	167	145	123
Spain	11	36	68	70	88	122	107
Poland	11	58	204	224	82	110	186
Europe	46	97	192	226	153	151	156

Triennial average data based on the benchmark year, except 1950.
Source: The same as Table 1.1. For details, see the Appendix.

By contrast, from the mid-1980s until the beginning of the twenty-first century the level of chemical fertilisers used per hectare fell throughout the continent. On the one hand, the Western, Mediterranean and Nordic countries reduced their consumption, due to environmental problems caused by the massive use of these inputs (Gardner 1996). Furthermore, in the 1990s directives reflecting the increasing concern for the environment, such as the Nitrate Directive in 1991, were approved (Brouwer and Silvis 2010). On the other hand, the Central and Eastern European countries also drastically reduced their consumption of this

[14]The United Kingdom was already consuming almost 1.5 million tons of artificial fertilisers by the second half of the 1930s, while in 1950-1951 use had increased to over four million tons (Brassley 2000).

input, because of the liberalisation of the factor markets, causing nominal input prices to increase by more than nominal output prices, and because of the problems which they suffered in general during their transition to market economies (Trzeciak-Duval 1999, Forstner and Isermeyer 2000, Anderson and Swinnen 2009).

Table 1. 6. Tractors per hundred workers

	1950	1962	1972	1982	1992	2000	2005
Western Europe	4.97	23.79	50.21	78.90	97.36	114.61	125.89
Mediterranean Europe	0.51	3.19	11.53	26.38	48.35	73.24	92.59
Nordic Europe	4.58	25.33	49.59	78.76	101.49	119.13	137.80
Central and Eastern E.	0.27	1.36	3.56	10.92	18.80	26.23	32.04
GFR/Germany	2.72	28.87	71.64	98.25	94.97	97.56	115.26
GDR	0.69*	7.12	13.74	16.40	-	-	-
France	2.19	19.49	46.68	80.11	111.52	143.99	163.09
United Kingdom	26.16	50.02	63.80	74.40	82.47	94.77	99.94
Italy	0.66	5.17	18.54	42.96	77.78	132.00	181.58
Spain	0.33	2.02	8.76	23.12	43.91	68.16	82.38
Poland	0.23	1.21	4.34	13.58	24.96	34.71	42.20
Europe	1.44	7.34	15.89	29.43	43.63	56.84	68.42

Triennial average data based on the benchmark year, except 1950.
* The datum for tractors is an average between 1949 and 1952.
Source: The same as Table 1.1. For details, see the Appendix.

With regard to the use of machinery, well represented by the number of tractors in service per agricultural worker, Table 1.6 shows an enormous growth throughout the second half of the twentieth century (a 7.3 per cent annual increase between 1950 and 2005). In the 1950s the growth in the number of tractors per worker was spectacular (14.6 per cent annually between 1950 and 1962)[15]. In the 1960s and 1970s the incorporation of tractors per agricultural worker also increased, although at a slower pace than in the preceding decade. In the following decades their use increased still further, despite the rate of growth falling once more. The probable reasons explaining this progressively lower growth are the

[15] For example, in the Spanish case the number of tractors increased by 16.3 per cent annually between 1950 and 1962, a considerable increase and above average annual European growth, despite the administrative barriers which existed (Clar 2009).

increase in the power of tractors over time and a gradual optimisation of agricultural machinery, due to the increase in farm size[16].

The Western and Nordic countries were the first to introduce this innovation, because the development of their economies preceded that of the Mediterranean, Central and Eastern European countries. By 1950 they already had, as with fertilisers, a far higher level than in the remaining countries. In the United Kingdom the level was already extremely high in 1950 and the adoption of this input took place above all during the 1940s, when the number of tractors quintupled (Brassley 2000). The security provided by high prices, due to trade protection and subsidies from national policies prior to the subsequent CAP allowed investment in machinery to be high (Houpt et al. 2010). The development of a rural credit market, principally in market economies, also played a fundamental role in the growing purchase of agricultural machinery (Josling 2009).

During their Communist stage, the countries of Central and Eastern Europe implemented a policy of the massive capitalisation of agriculture, especially of collectivized farms, permitting them to increase the number of tractors per worker at the same rate as other countries with market economies (Diamond et al. 1983, Landau and Tomaszewski 1985, Berend and Ranki 1985, Lampe 1986, Gregory and Stuart 2001). Following the transition, this proportion fell slightly (moving from 20.06 in 1990 to 18.07 in 1992), but rapidly increased once more, due also to the decrease in the number of workers.

It is important, lastly, to underline the weight of biological innovations in this process of technological change. The increase in crop yields due to the process of the genetic selection and hybridisation of seeds is fundamental to understanding the sharp increase in agricultural production and productivity[17].

[16]A growing complexity in the types of agricultural machinery could have influenced this lower growth. We have only taken into account tractors, because of the problems in obtaining data for other agricultural machinery.
[17]The improvement of yields in, for example, wheat or maize was substantial from the 1950s on. (Olmstead and Rhode 2008, Pujol 2011).

Table 1. 7. Active population in agriculture (thousands)

	1950	1962	1972	1982	1992	2000	2005
Western Europe	11,179	7,532	5,228	3,889	3,047	2,402	2,109
Mediterranean Eur.	16,391	13,691	9,734	7,454	5,345	4,071	3,548
Nordic Europe	1,904	1,229	895	705	515	398	343
Central & Eastern E.	30,134	27,262	22,239	15,958	11,790	8,877	7,397
GFR/Germany	5,114	3,466	1,965	1,497	1,446	1,014	820
GDR	2,112	1,411	1,064	916	-	-	-
France	6,335	4,139	2,792	1,863	1,244	880	723
United Kingdom	1,242	935	728	702	607	528	500
Italy	8,588	5,937	3,779	2,652	1,870	1,255	1,029
Spain	4,853	4,616	3,505	2,471	1,746	1,326	1,193
Poland	7,090	6,923	6,508	5,245	4,684	3,766	3,351
Europe	66,834	54,592	41,125	30,418	22,143	16,762	14,218

Triennial average data based on the benchmark year, except 1950.
Source: The same as Table 1.1. For details, see the Appendix.

Agricultural labour is the last principal input analysed in this section. In the second half of the twentieth century European agriculture used a progressively smaller labour force. As Table 1.7 shows, this fall was very intensive, from over 66 million workers to fewer than 15 million between 1950 and 2005. All European regions were severely affected by the rural exodus. Although their rates were different, the decrease in the labour force in agriculture in the entire period does not offer great contrasts. In Western Europe and the Nordic countries, the reduction of labour employed in agriculture was 81 percent between 1950 and 2005. In Mediterranean countries this was 78 percent and in the countries of Central and Eastern Europe 75 per cent. In this decline, two periods stand out: the first between 1950 and the mid-1980s and the second from the mid-1980s until today. In the first period, the average annual decrease was lower (-2.5 per cent), but in absolute terms almost 37 million people on the continent ceased working in agricultural activities. In turn, from 1982 until 2005 this annual decrease was still greater (-3.3 per cent). This accelerated fall in the active population in agriculture in the second period is probably due principally to the continuation of the process of rural exodus in the Mediterranean, Central and Eastern countries of Europe. Furthermore, the Central and Eastern countries, in particular Poland, the Czech

Republic, Slovakia and Hungary experienced considerable exits of workers between 1989 and 1995[18].

The exit of workers from European rural zones was directly determined by the need for labour in other sectors. For the less developed countries the national pull effect was complemented by the expansion of labour demand in other, more developed parts of Europe, which favoured rural emigration abroad. In fact, the powerful pull effect (derived from the high general economic growth of this period) was combined to a similarly powerful push effect (derived from labour-saving innovation in agriculture). The result was an unprecedented rise in the productivity of those farmers and labourers remaining in the agricultural sector (Collantes and Pinilla 2011:159-162, Martín-Retortillo and Pinilla 2015).

The most advanced countries in Western Europe had already experienced, prior to the Second World War, a very significant transfer of workers from rural to urban zones. Following the end of the conflict, the intense economic growth which took place proved capable of absorbing new and significant contingents of rural labour, especially in the 1950s and 1960s (Holderness 1996). The greater attraction of the urban environment for young generations in these advanced countries contributed to increasing yet further the exit of youths from the rural environment (Josling 2009).

The lower level of economic development in the Mediterranean, Central and Eastern European countries meant a less important rural exodus prior to 1945. Nevertheless, especially in the initial decades of the twentieth century, internal migrations were quite intense in countries such as Spain or Italy (Silvestre 2005). Immediately after 1945 the exit of agricultural workers from them was still of little importance, with the exception of Italy, but from 1960 onwards accelerated sharply. In the countries of the Communist bloc, certain policies delayed the replacement of workers by machinery and introduced migratory controls to restrict the mobility of labour power (Landau and Tomaszewski 1985).

[18]The *länder* corresponding to the former German Democratic Republic lost many workers following the transition, since this sector had an excessive labour supply. The exception to these countries was Romania, which experienced an annual increase in its agricultural labour force of 2.4 per cent between 1989 and 1995 (Huber 2000, Macours and Swinnen 2000).

IV

In this section, our objective is to unravel the growth of European agricultural output. We have seen so far how European agricultural production increased spectacularly from the early 1950s until the mid-1980s. These four decades of expansion of agricultural output were followed by years in which the most common result was the stagnation of production. We wish now to analyse what has been most decisive in the long-term growth of agricultural production.

In the previous section we were able to establish clearly that in the long term the use of traditional agricultural inputs, land and labour, has decreased notably. This fall in the use of both inputs, linked to the increase in production, has meant a sharp rise in both land and labour productivity (Wong and Ruttan 1990, Martín-Retortillo and Pinilla 2015). Consequently, the increase in production can only be explained by a greater use of capital or by efficiency gains in the use of inputs. Disentangling which of these factors has been more important requires the estimation of, firstly, how total factor productivity has varied, and, secondly, of the rate at which the use of capital in European agriculture has increased.

We shall calculate TFP in accordance with its primary definition, that is to say as the Solow residual (Solow 1957). This definition stems from the methodology of growth accounting[19]. We measure TFP indirectly as a residual component of the growth in output which cannot be explained by the growth of production inputs. This difference is calculated by subtracting from the annual growth rate of production between two years the rate of a combination of inputs. This combination comprises land, measured in hectares of arable land (A); labour, represented by the active population in the agricultural sector (L); and physical capital (K), measured as an average among the rates of growth of the number of

[19] Crafts states that the methodology of "growth accounting" is the most appropriate to quantify the impact of a new technology on productivity. (Crafts 2010).

tractors, tonnes of consumption of fertilisers, hectares of area equipped for irrigation and number of livestock (Table 3, 4, 5 and 6)[20].

This combination of inputs, according to the determinist methodologies of growth accounting, uses as weightings the fraction of the output employed to remunerate each productive factor (del Gatto et al. 2011). Based on Dias Avila and Evenson (2010):

$$G_{TFP} = G_Y - C_L G_L - C_A G_A - C_K G_K$$

where *G* represents growth rates in variables and *C* are weightings.

To simplify our calculation, and faced with the difficulty of obtaining for each country the remunerations of the productive factors, we have used the weightings proposed by Federico, which means that in the initial year of the calculation the distribution was 40 per cent each for land and labour and the remaining 20 per cent for capital, while for the final year the remunerations of the inputs were equivalent (Federico 2011: 62-66)[21]. Thus, we obtain the TFP, which is calculated as the average of the weightings of the initial year and those of the final year for each input (Jorgenson 1991, Olavarría et al. 2004).

The TFP of European agriculture, shown in Tables 8 to 10, experienced an enormous increase throughout the period[22]. Nevertheless, its rates of growth and its contribution to the increase in output show significant regional contrasts. For the whole period 1950-2005 (Table 1.8), the growth of production is explained by

[20]Fertilizers are considered working capital, because they are included 'in the amount of outlays for productive expenditures', Federico (2005: 52). This combination is based on that used by Federico for his calculation of TFP. Furthermore, we have replaced the geometric average by the arithmetical average to calculate capital growth rates, due to growth rates being negative for some periods or inputs. It should be observed that our estimation of capital growth, since it does not use other forms of capital, such as seeds, fuel and purchases of inputs from other sectors, involves assuming that its growth was similar to that obtained with those variables we do use. Despite this, TFP measurement includes the possible adjustment of quality in some inputs (Federico 2011: 62-66).

[21] Changes in input shares show the trend of technical change (Wang et al. 2012).

[22] Our estimation may suffer from a problem of overestimation, as the increase in part-time work in the period means that the reduction in the use of the labour factor was less marked. The ideal measurement of labour would be in hours worked, yet the only database to include this variable is EUROSTAT, but does so neither for all countries nor for the whole period.

the increase in TFP and the use of capital, which more than compensated for the fall in the use of land and labour[23].

Table 1. 8. Annual growth rates of outputs, inputs and TFP between 1950 and 2005

	Output	Labour	Land	Capital	TFP
Germany	1.24	-3.88	-0.22	1.00	2.48
Austria	1.35	-3.35	-0.44	3.37	1.84
Belgium-Luxembourg	1.44	-3.18	-0.34	2.75	2.00
Denmark	1.18	-3.13	-0.27	2.13	1.86
France	1.48	-3.87	-0.14	2.43	2.31
Ireland	1.47	-2.09	-0.18	2.52	1.63
Netherlands	1.84	-1.87	-0.11	1.84	2.08
Switzerland	0.63	-1.53	-0.23	1.22	0.95
UK	1.06	-1.64	-0.41	1.04	1.54
Western	**1.37**	**-2.98**	**-0.22**	**1.95**	**2.02**
Greece	2.07	-1.16	0.13	3.16	1.61
Italy	0.89	-3.78	-0.87	3.08	1.78
Portugal	0.90	-1.73	-1.09	2.24	1.34
Spain	2.34	-2.52	-0.20	3.64	2.37
Mediterranean	**1.48**	**-2.74**	**-0.46**	**3.06**	**1.84**
Finland	0.87	-3.66	-0.18	3.18	1.43
Norway	0.42	-2.36	0.12	2.20	0.65
Sweden	-0.01	-2.85	-0.61	1.31	0.91
Nordic	**0.32**	**-3.07**	**-0.36**	**1.88**	**1.08**
Albania*	2.60	0.37	0.81	2.33	1.55
Bulgaria	0.43	-5.01	-0.45	1.07	2.15
Czechoslovakia	0.58	-2.38	-0.28	1.37	1.19
Hungary	0.99	-3.10	-0.34	2.76	1.52
Poland	0.63	-1.35	-0.44	3.01	0.49
Romania	1.47	-3.44	-0.02	4.85	1.45
Yugoslavia	1.72	-3.35	-0.32	4.22	1.94
Central and Eastern	**0.94**	**-2.65**	**-0.30**	**3.29**	**1.15**
Europe	**1.26**	**-2.76**	**-0.31**	**2.18**	**1.80**

*The growth rates refer to the period 1962-2005 because there are no data for Albania in the 1950s.
Triennial averages have been used, based on the benchmark year, for the calculation of all growth rates, except for the active population, arable land and tractors for the year 1950 and for livestock units for Bulgaria, Czechoslovakia, Hungary, Romania, Spain and Portugal in the year 1950. When taking into account the data for 1950 and 2005 for the calculation of TFP, it was necessary to aggregate the data for the GDR and GFR to obtain a measurement for Germany.
Source: The same as Table 1.1. For details, see the Appendix.

[23] We have also estimated annual TFP growth, with logarithmic growth rates of output and inputs and distinct weights based on Fuglie (2010 and 2012) and Federico (2011). The differences among countries in TFP growth in this case are not large, in comparison with our main calculation, although obviously there are differences in the rates of TFP.

Our results show that regional differences in Europe were similar to the estimations of Fuglie (who calculates TFP growth for the period 1961-2007)[24]. In most Western European countries, the contribution of TFP was lower than the increase in the use of capital, although the two rates were similar. However, there are two exceptions within this group of countries; the United Kingdom and Netherlands experienced a greater increase in TFP than in the use of capital in the whole period[25]. The Mediterranean countries have a slightly higher TFP growth than the European average, but their use of capital increased much more than the wider European level. Furthermore, the difference between the rates of TFP and the use of capital was higher than in the Western countries. In the Nordic countries, the increase in TFP and in the use of capital was lower than in Western Europe. Lastly, in the Central and Eastern countries the increase in the use of capital was much higher than in other European groups of countries and almost three times more important than TFP.

The fastest increase in TFP took place in the countries of Western Europe and in Spain. The lowest growth rates corresponded to the remaining Mediterranean countries, the Nordic countries, Switzerland and the Central and Eastern countries.

We now analyse the evolution of TFP, and also that of output and inputs, by sub-periods. Table 1.9 underlines that in the period between 1950 and 1985 the strong growth of output was essentially explained by a very marked capitalisation, especially as a consequence of the generalisation of the use of self-propelled machines, chemical fertilisers, high-yielding seed varieties and pesticides, added to the sharp increase in livestock units in some countries such as Benelux, Denmark, Greece, France and Spain[26]. An improvement (very significant in the countries of

[24]Their results of TFP annual rates of growth are: 1.59 for Northwestern countries, 1.15 for the Southern European region and 1.03 for Eastern Europe as a whole (Fuglie 2010 and 2012). The estimations by subregions in Europe, either each ten years or with other year periods to present the results as annual indexes hinders comparison with our results in the references appearing in endnote 4.

[25]The agricultural sector in the UK and the Netherlands was of lesser importance in the economy, due to the early industrialization processes in these countries. This sector had incorporated more technical inputs, as can be seen for the UK in Table 6.

[26] The reason to divide the subperiods in 1985 is because European agricultural production followed a growing trend until 1985, from when on it stagnated. Thus, we want to explain the two different trends in European agricultural production.

Western Europe and more moderate in the rest) in efficiency in the European agricultural system as a whole also contributed to the strong rise in production, which was achieved while the use of land and labour were already falling.

Table 1. 9. Annual growth rate of output, inputs and TFP between 1950 and 1985

	Output	Labour	Land	Capital	TFP
GDR	1.72	-2.63	-0.07	2.83	1.96
GFR	2.35	-3.90	-0.39	2.72	3.20
Austria	2.07	-3.70	-0.56	5.22	2.24
Belgium-Luxembourg	1.86	-3.60	-1.03	4.55	2.34
Denmark	1.49	-3.08	-0.09	4.10	1.57
France	2.29	-3.72	-0.28	4.08	2.66
Ireland	2.12	-2.51	-0.68	3.82	2.27
Netherlands	2.93	-2.36	-0.60	3.17	3.17
Switzerland	1.21	-1.74	-0.49	2.53	1.35
UK	1.85	-1.73	-0.16	1.81	2.06
Western	**2.14**	**-3.14**	**-0.28**	**3.26**	**2.53**
Greece	3.02	-0.62	0.36	5.02	1.78
Italy	1.32	-3.53	-0.89	5.11	1.58
Portugal	0.87	-1.20	-0.33	3.38	0.54
Spain	2.92	-2.20	0.09	5.00	2.36
Mediterranean	**1.94**	**-2.48**	**-0.26**	**4.58**	**1.73**
Finland	1.56	-3.50	-0.24	5.57	1.45
Norway	0.79	-2.34	0.16	3.45	0.67
Sweden	0.35	-2.76	-0.71	2.20	1.04
Nordic	**0.77**	**-2.99**	**-0.43**	**3.19**	**1.18**
Albania*	3.42	1.87	1.67	5.56	0.64
Bulgaria	2.48	-3.70	-0.15	5.53	2.41
Czechoslovakia	1.88	-2.17	-0.18	3.66	1.76
Hungary	2.30	-2.76	-0.25	5.25	2.01
Poland	1.62	-0.87	-0.25	5.80	0.49
Romania	2.78	-2.67	0.30	9.37	1.15
Yugoslavia	3.12	-2.24	-0.01	7.50	1.94
Central and Eastern	**2.18**	**-2.08**	**-0.08**	**6.34**	**1.28**
Europe	**2.07**	**-2.41**	**-0.20**	**3.92**	**1.98**

*The growth rates are for the period 1962-1985 because there are no data for Albania in the 1950s.
Triennial averages have been used, based on the benchmark year, for the calculation of all growth rates, except for the variables of active population, arable land and tractors for the year 1950 and for livestock units for Bulgaria, Czechoslovakia, Hungary, Romania, Spain and Portugal in the year 1950.
Source: The same as Table 1.1. For details, see the Appendix.

The relative contributions of capital and TFP vary according to country type. In the Western countries and the German Federal Republic, TFP growth was higher than the European average. In the Mediterranean countries, this growth

was slightly lower than Europe as a whole because of a stronger capitalization process than in the Western countries, as these had advanced this process further before the war. In the Nordic countries the TFP contribution was lower than the average? European level, but their output growth was the lowest on the continent. In the centrally planned economies, the contribution of capital was the highest on the European continent, but TFP increased, although slightly, as capital growth was almost five times higher than TFP growth. This was due to the majority of countries having concluded the collectivization process, which permitted farmers to enjoy a certain institutional stability[27]. However, Federico demonstrates a lack of incentives to work on collectivized farms, and similarly a reformulation of agricultural policy due to the excessive use of capital in a still backward agriculture (Federico 2005 and 2011).

Finally, Table 1.10, with regard to 1985-2005, displays a change with respect to the situation observed thus far. The growth of TFP in this period is somewhat lower. The real change was produced because capital began to decrease, as had occurred previously with the other productive factors. Furthermore, output growth halted in Europe as a whole (as the result of the stagnant growth of Western Europe and a fall in that of Germany, the Nordic countries and Central and Eastern Europe). Only the Mediterranean countries, particularly Spain, had somewhat higher annual growth rates of production. These two changes are related. The limitation on the use of composts and fertilisers, due to abuse in preceding decades and the environmental problems it produced, affected production. In fact, this fall in the use of fertilisers is reflected in the negative growth of capital, also produced partly by the slight decreases in the number of animals and of tractors. Thus, it is efficiency gains in the agricultural sector as a whole which permitted slight increases in production, given a lower use of all productive factors. The less developed countries of the European market economies, namely the Mediterranean ones, are those which displayed different behaviour. Their TFP growth was even higher than in the previous period.

[27]In countries such as Poland this institutional stability was absent, due to various legislative modifications regarding the incentives to invest in collective farms, the dissolution of a number of cooperatives following a process of forced collectivisation, and similarly the loss of consistency in government action, which permitted farmers to acquire land for crops to avoid urban growth and a rural exodus; in fact, this policy only incentivised the purchase of land for the socialised farms (Landau and Tomaszewski 1985 and Pryor 1992).

Table 1. 10. Annual growth rates of output, inputs and TFP between 1985 and 2005

	Output	Labour	Land	Capital	TFP
Germany	-0.41	-4.60	-0.14	-1.93	1.84
Austria	0.09	-2.72	-0.23	0.25	1.11
Belgium-Luxembourg	0.73	-2.44	0.89	-0.30	1.38
Denmark	0.63	-3.20	-0.59	-1.21	2.34
France	0.10	-4.14	0.10	-0.36	1.67
Ireland	0.35	-1.35	0.70	0.34	0.50
Netherlands	-0.03	-1.01	0.75	-0.44	0.18
Switzerland	-0.38	-1.15	0.23	-1.01	0.23
UK	-0.30	-1.48	-0.84	-0.26	0.62
Western	**0.03**	**-2.70**	**-0.12**	**-0.30**	**1.15**
Greece	0.43	-2.11	-0.26	0.06	1.28
Italy	0.14	-4.23	-0.84	-0.30	2.08
Portugal	0.96	-2.64	-2.41	0.30	2.73
Spain	1.33	-3.08	-0.69	1.33	2.36
Mediterranean	**0.67**	**-3.21**	**-0.81**	**0.48**	**2.02**
Finland	-0.33	-3.96	-0.07	-0.84	1.37
Norway	-0.24	-2.39	0.04	0.08	0.60
Sweden	-0.65	-3.00	-0.44	-0.23	0.68
Nordic	**-0.47**	**-3.20**	**-0.23**	**-0.37**	**0.89**
Albania	1.67	-1.33	-0.18	-1.18	2.54
Bulgaria	-3.05	-7.27	-0.97	-6.22	1.62
Czechoslovakia	-1.65	-2.74	-0.46	-2.47	0.18
Hungary	-1.26	-3.69	-0.48	-1.23	0.60
Poland	-1.07	-2.19	-0.76	-1.68	0.46
Romania	-0.79	-4.77	-0.60	-2.42	1.83
Yugoslavia	-0.69	-5.26	-0.86	-1.14	1.86
Central and Eastern	**-1.19**	**-3.64**	**-0.69**	**-1.82**	**0.89**
Europe	**-0.15**	**-3.37**	**-0.50**	**-0.77**	**1.48**

Triennial averages, based on the benchmark year, have been used for the calculation of the growth rates. Data for Czechoslovakia and Yugoslavia were aggregated following their dissolution.
Source: The same as Table 1.1. For details, see the Appendix.

A different case is that of the countries of Central and Eastern Europe, which experienced a sharp fall in their agricultural production, and similarly in the use of inputs, especially labour and capital. This is due to the range of problems caused by the economic transition from a centrally planned economy to a market one[28].

[28] There also existed problems in the German Democratic Republic in comparison with the Federal Republic of Germany. In the mid-1990s there existed differences between capital, labour and

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European agricultural production grew strongly until the mid-1980s, stagnating from then on. During the first stage of rapid growth a process of intensive capitalisation of the sector occurred, as against reductions in the use of labour and land. Furthermore, sharp increases in productivity permitted the improvement of efficiency in this sector and also the increase of production yet further.

In turn, from the late 1980s onwards the transformation of the productivist model of the CAP to another in which agricultural income support was partially decoupled from production, and similarly the transition from a centrally planned system to a market one in the countries of the ex-Communist bloc, affected production; this continued to reduce the use of land and labour and, in turn, maintained or reduced the role of capital. Faced with these reductions in factor employment, it was the increases in the total productivity of these same factors which permitted production to be maintained.

The present study has highlighted diverse ways of accomplishing high production growth in the long term. From our perspective we can distinguish two different models and one intermediate one.

The first is characteristic of the countries of Western Europe and Germany. At the beginning of the period, these countries had a more advanced level of economic development and higher capitalisation of their agriculture. These were based on strong increases in agricultural efficiency, with an annual mean growth rate which exceeded 1.5 per cent in the 55 years studied. The increase in the use of capital played a very important role, although its significance waned by the end of the period. Capital investment grew extraordinarily quickly in the 1950s, decelerated in the 1960s and 1970s (although it continued to increase significantly) and fell from the 1990s on. This model combined, therefore, a

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livestock per hectare, and also between yield per hectare and input quality between the two Republics. Inefficiency in the GDR resulted from the assignation of inputs and the size of farms, not from ownership type. (Thiele and Brodersen 1999, Macours and Swinnen 2000 and 2002).

considerable fall in the use of land and, above all, labour, with a significant growth of capital, while efficiency improvement played a prime role.

The opposing model is that of the countries with centrally planned economies. In them the key to growth in agricultural production was the very strong increases in the use of capital, much higher than those of the Western countries, while the use of land and labour similarly diminished. The efficiency of the system improved, but by considerably less than in the rest of Europe. In short, their model of agricultural growth resembled that of their economies as a whole, in which efficiency considerations played a secondary role compared to the accumulation of the capital factor (and labour in non-agricultural activities) (Maddison 1989). The transition to a market economy seriously affected their production, and also upset their model of growth, by significantly reducing the use of capital and maintaining efficiency improvement. A certain, although still slight, convergence towards the Western? model took place.

The intermediate situation is that of the lesser developed countries in the southern European periphery and the Nordic countries, although between these two groups there were also important differences. Their development model was based more on the increase in capital than on efficiency improvement, but in distinction to those of the Soviet bloc, they tended to converge much earlier with the model of the Western countries. In the 1950s their growth was based very unequally on the increase in capital, as against efficiency. By contrast, from 1960 onwards, although the use of capital grew rapidly, so did efficiency, at a rate which approximated that of the Western countries. From 1985, although in distinction to the Western countries the use of capital continued to increase in the Mediterranean countries, its rate was slow and efficiency increased even more quickly than the Western countries, showing a tendency to converge, especially in Spain and Portugal. In the Nordic countries the use of capital also fell from 1985 on, as in the Western countries.

In summary, the growth of agricultural production in Europe shows paths which differ but which tended towards a certain convergence. A model strongly based on efficiency increase was categorically followed by the more advanced countries since the early 1960s and by the more backward countries of the

southern periphery from the early 1980s. The countries of Central and Eastern Europe had to wait to perform their transition to market economies, to then follow a similar model from the mid-1990s.

But what is there behind such an important role for efficiency improvement in European agriculture in the second half of the twentieth century? In great measure, this strong growth was derived from the massive adoption of technologies which permitted land and labour to be saved, while production increased or was maintained. Technology and technical progress, as we have seen, played a fundamental role in European agriculture throughout this period. Technological innovation materialized in a significant and growing use of capital inputs, which despite having been introduced before the Second World War in the most advanced countries, now spread to an unprecedented degree. The adoption of technological change and the conditions which permitted its generation were without a doubt closely linked to the type of economy and society which developed in Europe following the Second World War (Gallego 2007). In this way, high-income economies, characterized by a continuous adoption of innovations oriented towards efficiency improvement, steered agriculture towards a model of growth which was not significantly different from the general model of economic growth.

Perhaps the principal difference was the importance to agriculture of public policies oriented towards the maintenance of agricultural incomes, which considerably limited the role of the market. It is not that the public sector and government policies were not important in the remaining economic activities, but rather that in agriculture their role was much more decisive, due not only to the establishment of prices or the protection of the internal market, but also more dynamically, such as the stimuli supplied by public research efforts. Investigation into creating and improving machinery, into chemical fertilisers and into the genetic selection of seeds to improve yields, among other research, meant a very strong boost to technical processes and, therefore, to TFP. Agricultural extension services facilitated the diffusion of new technologies, coming to play an important role in the increase in TFP.

The countries with centrally planned economies departed from this model. Their strategy of a huge use of the capital factor in agriculture and a certain disdain

for efficiency is congruent with their general model of economic growth. The countries of the southern European periphery, although they also initially based their agricultural growth on heavy injections of capital, attempted from a relatively early period to improve their efficiency, following (although with limitations) the model of agricultural development previously employed by the countries of Western Europe. Yet this growth of TFP does not only show technical progress, but also a measurement of efficiency in the system as a whole. Its TFP growth was also based on an improvement in factor allocation, that is to say sound economic policies (Federico 2011: 66).

In conclusion, it can be stated that although the present study validates the general hypothesis, originally proposed by Federico (2005), regarding the highly intensive agricultural growth in this period, the European case qualifies the hypothesis in two directions. Firstly, it highlights the close interconnection between TFP growth and the use of modern capital inputs. Secondly, at the regional level in Europe it can be concluded that there were significant differences in the contribution to output growth of capital and TFP.

Appendix

Groups of countries: The countries which constitute the Western Europe group are: Austria, Belgium-Luxembourg, Denmark, France, Ireland, the Netherlands, Switzerland and the United Kingdom [29]. The countries included in the Mediterranean group are: Greece, Italy Portugal and Spain. Three countries comprise the Nordic group: Finland, Norway and Sweden. The market economies group is formed by these three groups of countries. The last and final group, Central and Eastern Europe, is constituted by Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Rumania and Yugoslavia. The data for Czechoslovakia and Yugoslavia are aggregated after their dissolution in 1992 and 1993, respectively.

[29] The data for Belgium-Luxembourg are aggregated in the FAO and FAOSTAT databases until 2000. We then aggregated the data to homogenize an annual series.

Data sources for the tables: Authors´ compilation, using FAOSTAT (2009) as a base. The 1950 data for all the variables has been elaborated using the FAO Production Yearbook (1948-2004). Data for the two Germanys prior to 1992 are the authors' compilation, based on the FAO Production Yearbook.

Calculation of variables:

If there are no data for some years we have obtained them through linear interpolation from among the statistics available from the data sources.

Production: The data are for net production, which is gross production minus seeds and feedstuffs.

The data have been extracted from FAOSTAT and the FAO Production Yearbook in the following way. The data from 1962 to 2005 were downloaded from FAOSTAT. These represent the level of net production at 1999-2001 prices in international dollars. The only exception to this procedure was the case of Germany. The data corresponding to the Federal Republic of Germany and to the German Democratic Republic have been calculated using the 1999-2001 prices from Germany, downloaded from FAOSTAT and multiplied by physical production extracted from the FAO Production Yearbook (1948-2004). Prior to 1961 FAOSTAT does not offer production data, but the annals of FAO Production Yearbook do however facilitate numerous indices of gross production from 1948, with a base firstly at the pre-war level and later in 1953[30]. To obtain a complete annual series from 1948, we have employed the evolution of those statistics indicating the indices of gross production, comparing the 1961 value of net production with the index number for the same year. Obviously, we are assuming that the evolution of the gross production and net production are equivalent. In this way we calculate net production until 1953. Prior to that year the base level in the numerous indices

[30]The index offered by FAO is the production of crops and livestock products for human consumption, adding fibres, tobacco, industrial oilseeds and rubber and substracting crops and skim milk used as feed in livestock production.

calculated by the FAO Production Yearbook is the pre-war level. Thus, we calculate the evolution between 1948 and 1953 by comparing the production level obtained in 1953 with the index number of the same year with its base at the pre-war level.

In FAO (1948-2004) there are no indices of agricultural production for the Central and Eastern European countries. To measure their net production 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 agricultural production for each country; the sources are Berend and Ranki (1985) and Landau and Tomaszewski (1985) respectively. We have taken as reference net production in 1961 and assumed that the evolution of agricultural production in the 1950s followed the trend given in these indexes. For Bulgaria, Czechoslovakia, the German Democratic Republic and Romania, we have obtained production in quantities during the 1950s from FAO (1948-2004). We have calculated production in 1999-2001 dollars using prices from FAOSTAT (2009). Such calculations have 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 for the 1950s taking net production in 1961 as reference.

The pre-war index number base period for FAO is 1934-1938, with the exceptions of West Germany and Greece (1935-38) and Spain (1931-35).

For the case of Albania, we have assumed that agricultural production between 1950 and 1961 followed the evolution of crop production, which is available for the 1950s in the FAO Yearbooks.

Agricultural workers: The population censuses do not permit us to establish the number of part-time workers in agriculture, as they are not registered in this activity. Similarly, it is not possible to determine whether the workers registered in the sector dedicate all their time to farm work. Consequently, it would be convenient to measure the active agricultural population in hours worked (Federico 2005 and 2011). Faced with the difficulty of finding reliable databases for broad spatial and temporal samples of this variable, we decided to measure the active population in agriculture by the number of workers. This variable, although

it differs from the true labour force, can describe in broad outlines the sharp decrease in the real human labour force which agriculture experienced after 1945.

The datum for Albania in 1950 has been estimated. We have assumed that the active population and the number of tractors (Tables 6 and 7) follow the same evolution as Yugoslavia between 1950 and 1961.

Land: The datum for Albania in 1950 is that of 1959.

Area equipped for irrigation: the FAOSTAT database begins in 1961. We have completed the decade of the 1950s with data from the FAO Production Yearbook for Greece and Spain. For the rest of the countries either there are no data or the data offered by FAO and FAOSTAT display significant differences in their definition, and consequently we have assumed that this variable remains constant.

The datum for Albania in 1950 is that of 1953 (FAO 1948-1976).

Livestock units: This is a weighted average in which the weightings are obtained from Hayami and Ruttan (1985), and the species taken into account, together with the weightings in parentheses, are: donkeys or asses (0.8), buffalos (1), horses (1), goats (0.1), pigs (0.2), chickens (0.01), cattle (0.8), geese (0.01), mules (1), sheep (0.1), ducks (0.01) and turkeys (0.01).

In Portugal there are no data before 1957. We have assumed that the growth between 1950 and 1956 was at the same annual rate as in the period 1957-61.

In the case of Bulgaria there are no data for chickens before 1952. We have assumed that the figures for 1950 and 1951 grew at the same annual rate as in the period 1952-56.

The datum for Albania in 1950 is that of 1957.

Fertilisers: The datum for Albania in 1950 is that of 1959.

Machinery: The datum for Albania in 1950 is the average of 1949-1952.

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Chapter 2. On the causes of economic growth in Europe: Why did agricultural labour productivity not converge between 1950 and 2005?

2.1. Introduction

The literature on the causes of modern economic growth has hosted one of the most heated recent debates in economics. Rather than traditional so-called proximate causes, some more innovative research has insisted on the crucial role of fundamental causes, such as geography, institutions, trade or culture (Acemoglu et al. 2001 and 2005; Frankel and Rommer 1999; Sachs and Warner 1995; Sachs 2000). This debate, developed principally by economists, has frequently employed historical data to validate the hypotheses proposed. It is unsurprising, therefore, that its impact has deeply affected economic history research, in which the analysis of the causes of economic growth has habitually been a central topic.

In the case of European economic growth, a significant number of European economic historians have used comparative perspectives to address this question[31]. Such literature addresses this central problem of the causes of and obstacles to modern economic growth by analysing the rhythms and patterns of European economic development over the last two centuries.

For economic historians, European industrialisation and its successes, failures and rhythms have probably been one of the most relevant questions. Nevertheless, in the last two decades, the reasons explaining the extremely rapid growth in the years of the Golden Age and its abrupt ending in the 1970s, have also generated a debate of great interest (Temin 2002; Vonyo 2008; Eichengreen and Ritschl 2009).

The changes in agriculture and their influence on economic development have occupied a central place in the industrialisation debate (Allen, 2009; O'Brien and Prados 1992; Van Zanden 1991; Lains and Pinilla 2009). Surprisingly, in the discussion regarding economic growth in the Golden Age the debate has only centred on the possible contribution to economic growth made by the exit of labour power from agriculture (Temin 2002; Vonyo 2008). However, the analysis in the second half of the twentieth century of the causes of changes in the agricultural sector itself and their contribution to general economic growth, from a long-term perspective, have produced less interest. The most notable exception is the seminal study by Federico (2005), which tackles such causes for the world as a

[31]A recent synthesis can be found in Broadberry and O'Rourke (2010).

whole and from the perspective of two centuries[32]. The same is not true of agricultural economists, for whom agricultural growth in these decades, its causes and international differences have been a central topic (Hayami and Ruttan 1985; Fuglie 2010 and 2012). However, these studies have normally lacked a long-term perspective.

This scanty interest is surprising, bearing in mind that agricultural productivity increased fastest in these years. Furthermore, for many countries on the continent, by the 1960s the agricultural sector still employed most labour power and, additionally, made a substantial contribution to GDP. Moreover, the sector underwent other crucial changes. Firstly, it moved from having weak links with other sectors to becoming a sector in which the majority of inputs came from the industrial sector, which also purchased a very significant part of agricultural output for its subsequent transformation. Secondly, agriculture came to benefit from considerable state intervention. In Western Europe, agricultural policies had a decisive weight in the development of this sector, replacing the market to a considerable degree. In Eastern Europe, collectivization involved total control by the state.

Against this background, the present article aims to make a contribution to explaining the causes of and the differences in economic growth on the European continent, concentrating on the agricultural sector in the second half of the twentieth century. 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 occurred in the period in which the European-wide diffusion of technologies took place, significantly advancing the frontiers of production possibilities. Specifically, the study offers a long-term analysis of agricultural labour productivity differences in Europe. This issue is essential, since agricultural modernisation and its positive contribution to economic development require a substantial increase in productivity, which also permits a significant transfer of labour power to other sectors. It is also extremely important because it offers a good approximation of production and income per worker in this sector. Some recent studies have emphasised that since differences in agricultural productivity

[32] The studies by Grigg (1982) and Bairoch (1999) have also touched upon this subject.

are greater than in the economy as a whole, their understanding is key to the comprehension of the differences in income per worker among countries, and especially developing countries (Gollin et al., 2014 a).

As for shorter periods in agricultural economics, the present article systematically compares the evolution of European countries, using econometric techniques to provide explanations. To achieve the objective proposed, in addition to the so-called proximate causes of economic growth we shall also use variables which permit the introduction into the analysis of the role of fundamental causes, especially institutional or geographical factors.

The study period is particularly interesting, as it experienced the greatest growth in agricultural productivity in the last two centuries (Martín-Retortillo and Pinilla, 2015). Most previous analyses have employed a highly heterogeneous sample of 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 extremely difficult to obtain.

To be able to construct not only the descriptive statistics but also the econometric analyses, we found it necessary to compile a homogeneous database which fully covers the 1950-2005 period and which further includes all the countries of the European continent (with the exception of the ex-Soviet Union and its successor republics) (see Appendix). Our principal source is the FAOSTAT (2009) database and the paper yearbooks of the FAO (1948-2004). As explained in detail in the Appendix, the principal problems we have faced are related to the absence of net agricultural production data for the decade of the 1950s, territorial changes (especially in the case of the two Germanys prior to reunification, for which, additionally, there exist data for neither net production nor other variables) and the calculation of the human capital stock. All this has required the estimation of variables and their homogenisation (see Appendix).

The results show the importance of the land/labour ratio in understanding the lack of convergence in European labour productivity levels. That is to say, factors from outside the agricultural sector itself, namely the capacity of other sectors to attract agricultural workers, are very important for the explanation of labour productivity differences. Also significant were the endowments of

fertilizers, machinery, irrigated land or livestock capital per worker. This article argues that the exodus of workers and the far-reaching implementation of new production technologies contributed to increasing productivity levels. Lastly, the institutional framework was also of great importance. Especially in Western European countries, membership of the European Union encouraged high levels of productivity. For Eastern European countries, relatively low productivity levels were maintained, due to the centralised planning of their economies. The policies subsidising agriculture had a negative effect on productivity. In addition, geographical conditions also help to explain productivity differences. In short, we believe that this discussion permits deeper debate regarding the causes of European economic growth in the long term.

The article comprises six sections, including this introduction. Section 2 examines the evolution of agricultural productivity in Europe and analyses absolute convergence. Section 3 presents the theoretical model constructed, the econometric methodology followed and the variables employed. Section 4 discusses the results obtained. In section 5 we perform an analysis of agricultural productivity with a dynamic specification. Finally, Section 6 presents the principal conclusions.

2.2. The evolution of agricultural labour productivity in Europe

2.2.1. Agricultural labour productivity changes in Europe

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, was one of growth which was continuous and moderate but very unequal among countries. New techniques were adopted, such as crop rotations, the introduction of pulses and other fodder crops, the elimination of fallow periods, improved implements, more intensive fertilizing and new fertilizers such as guano (Allen 1992 and 1994; Clark 1987). The average annual growth of labour productivity was 0.93% in developed countries (data from Bairoch 1999).

The second stage was 1870-1950, in which annual growth accelerated to 1.23% in developed countries. The use of chemical fertilizers, biological innovations, reaping and threshing machines, new metal instruments and

concentrated feeds were all causes of this growth (Chorley 1981; Van Zanden 1991; Olmstead and Rhode 2002 and 2008; Federico 2003).

Table 2. 1. Labour productivity, production and productive factors in European agriculture, 1950-2005

Europe	Ag. labour productivity ($)	Net ag. prod. ($000,000)	Active ag. pop. (000 people)	Arable land and permanent crops (000 hectares)	Tractors (000 units)	Chemical fertilizers (000 tonnes)	Live animals (000 units of cattle)
1950	1,388	94,319	66,365	150,517	960	6,966	131,849
1962	2,378	129,713	54,592	151,854	4,002	14,803	155,744
1972	3,815	156,730	41,125	142,750	6,530	27,388	163,866
1982	6,173	187,643	30,418	140,337	8,945	31,676	175,453
1992	8,726	193,139	22,143	136,378	9,658	20,865	162,536
2000	11,661	195,392	16,762	131,313	9,520	19,834	148,442
2005	13,627	193,760	14,218	126,741	9,722	19,831	142,230
Annual rates of growth							
1950-1962	4.14	2.69	-1.61	0.07	12.63	6.48	1.40
1962-1972	5.31	1.91	-2.79	-0.62	5.02	6.35	0.51
1972-1982	4.93	1.82	-2.97	-0.17	3.20	1.47	0.69
1982-1992	3.52	0.29	-3.13	-0.29	0.77	-4.09	-0.76
1992-2005	3.49	0.02	-3.35	-0.56	0.05	-0.39	-1.02
1950-2005	4.23	1.32	-2.76	-0.31	4.3	1.92	0.14

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. The data for production in 1950 is the average between the data for 1950 and 1951. See the Appendix for more details on the data or countries included.
Source: Authors' calculation, from FAOSTAT (2009) and FAO (1948-2004)

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

Table 2. 2. Agricultural labour productivity, 1950-2005 (international 1999-2001 prices in dollars per worker) and annual growth rates from 1950 to 2005

	1950	1962	1972	1982	1992	2000	2005	1950-2005
GFR/Germany	1,591	3,988	7,911	12,290	17,237	26,003	31,037	5.45
GDR	1,881	2,985	5,442	7,401	-	-	-	-
Austria	1,207	3,078	5,488	9,539	11,351	16,555	18,284	5.07
Belgium-Luxembourg	4,933	9,906	19,008	30,185	42,341	53,281	58,360	4.59
Denmark	4,661	8,818	11,584	20,757	28,575	40,342	49,308	4.38
France	2,194	5,452	9,597	16,436	25,659	37,584	44,881	5.64
Ireland	2,777	4,435	7,464	12,521	19,671	21,948	21,625	3.80
Netherlands	4,712	9,675	18,142	28,311	32,267	33,997	35,635	3.75
Switzerland	3,581	5,613	7,641	10,494	10,158	11,559	12,859	2.35
United Kingdom	5,775	9,857	15,051	19,119	23,660	25,428	26,132	2.78
Western Europe	**2,935**	**6,285**	**10,756**	**17,397**	**24,040**	**30,522**	**33,774**	4.54
Greece	1,774	1,837	2,974	4,613	6,788	8,057	8,355	2.86
Italy	1,464	2,863	5,290	8,979	12,795	19,122	23,006	5.14
Portugal	1,211	1,752	2,215	1,897	3,490	4,377	4,892	2.57
Spain	1,330	2,017	3,451	6,127	10,361	16,043	18,001	4.85
Mediterranean E.	**1,426**	**2,334**	**3,961**	**6,255**	**9,551**	**13,459**	**15,259**	4.40
Finland	1,093	2,674	3,715	5,705	7,798	10,666	13,476	4.67
Norway	2,115	3,163	4,758	6,453	7,815	9,082	10,190	2.90
Sweden	3,665	5,111	6,883	9,816	11,511	16,050	18,137	2.95
Nordic Europe	**2,140**	**3,634**	**5,004**	**7,374**	**9,186**	**12,197**	**14,297**	3.51
Albania	360	472	593	691	697	1,048	1,191	2.20
Bulgaria	607	1,221	2,597	4,673	6,240	10,195	12,022	5.58
Czechoslovakia	1,324	2,212	3,824	5,156	6,549	6,608	7,576	3.22
Hungary	1,153	1,803	3,386	6,346	7,471	10,018	12,634	4.45
Poland	1,033	1,438	1,835	2,432	2,805	3,290	3,920	2.45
Romania	392	656	1,169	2,182	2,504	3,531	5,835	5.03
Yugoslavia	363	545	888	1,935	3,180	4,038	5,323	5.00
Central and Eastern Europe	**679**	**1,030**	**1,631**	**2,703**	**3,332**	**4,073**	**5,138**	3.75
Europe	**1,388**	**2,378**	**3,815**	**6,173**	**8,726**	**11,661**	**13,627**	4.24

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), except for 1950. The calculation for Germany in 1950 has been made considering its productivity as if it were a single country, its value being 1,676. For more details, see the Appendix.
Source: Authors' calculation, from FAOSTAT (2009) and FAO (1948-2004)

To analyse the period 1950-2005 more precisely, Table 2.1 offers our own calculation of agricultural labour productivity in Europe as a whole, and its

agricultural production and principal productive factors[33]. To obtain labour productivity, we divided net production in dollars at international prices in 1999-2001 by the total active agricultural population. Average annual European growth in this period was 4.23%, the highest rate in the last two centuries.

Labour productivity growth was especially rapid until the early 1980s, increasing somewhat more slowly from then on. This growth was based on a substantial increase in production until the beginning of that decade, after which it rose very slowly. 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, 1950-1982, resulted from a sharp 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, 1982-2005, cultivated land decreased further, as did the number of livestock units and, particularly, the use of fertilizers. The number of tractors subsequently rose very slowly. This meant that the maintenance of production, while the use of productive factors fell, was only possible as a result of a notable increase in TFP (Martín-Retortillo and Pinilla, 2015).

By disaggregating the evolution of labour productivity by countries it is possible to show the very different patterns followed (Table 2.2).

Throughout the period, Western European countries had productivity levels far above European averages, and productivity growth higher than the Continental norm. Their highest levels of productivity, in 1950, can be explained by their advantage in terms of economic development. They completed their processes of industrialisation earlier, which means that their structural change was also more advanced. This involved a greater exit of the rural population to industry and services and the necessary replacement of the agricultural labour force by machinery. The result is that they started from a higher level of labour productivity, while the adoption of new innovations and the deepening of structural change allowed them to maintain that advantage. These countries display different evolutions. The United Kingdom or the Netherlands have

[33] Farm production does not include forestry products.

displayed decelerating growth in recent years, despite their high initial level (Brassley 2000). Others, for example France and Denmark, have been able to maintain high growth rates. Swiss productivity had an unusual low growth due to its flat production increase and a lower decrease in the active population than the rest of the Western countries.

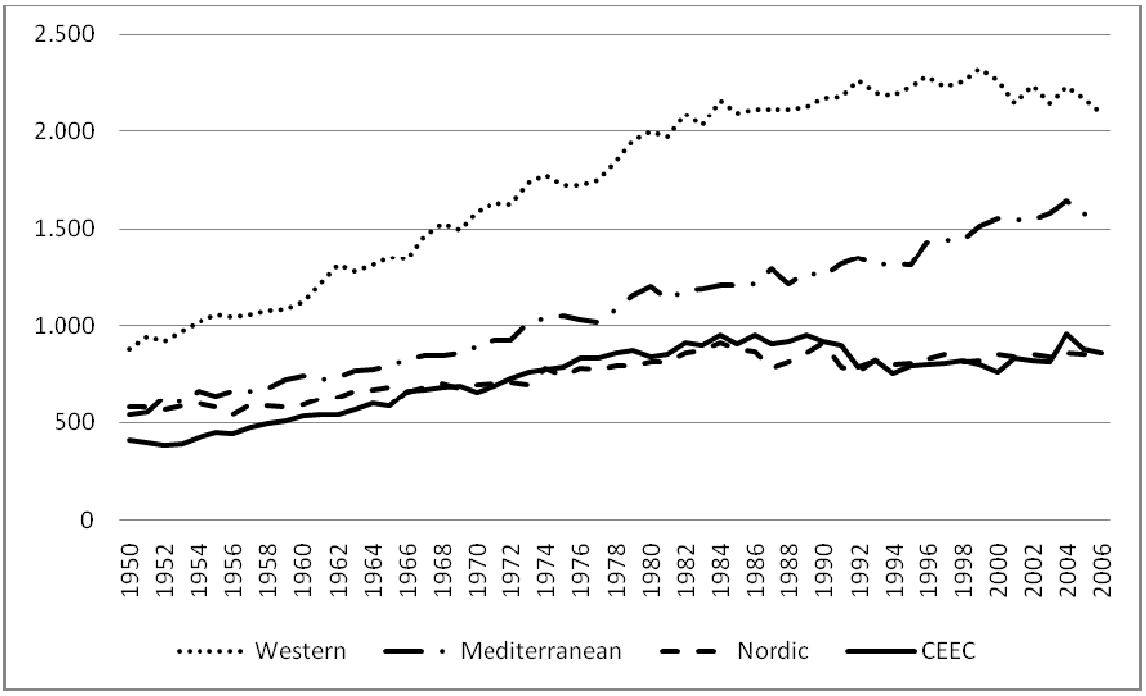
The Nordic countries experienced greatly varying levels of agricultural productivity, but ranged around the European average. From 1950 to 2005 their growth was lower than or similar to European growth, which meant a loss of their relative positions on the continent.

In 1950 productivity in the Mediterranean countries (except Italy) was lower than in Europe as a whole, and two different trajectories are apparent. One is the very strong growth of Spain and Italy, while Greece and Portugal were clearly outpaced by this sharp rise in production.

Lastly, the active agricultural population in the Eastern European countries was much less productive than in Europe as a whole. Growth from 1950 to 2005 was extremely heterogeneous. Despite this heterogeneity, these countries and the Soviet Union incorporated many of the innovations being adopted by other European countries. This led to notable increases in production between 1960 and 1990 (Diamond et al. 1983). Consequently, agricultural labour productivity increased in the Eastern countries prior to the collapse of Communism. In the 1990s, by contrast, agricultural production declined, due to the implosion of the centrally planned economies. The transition to a market economy shows great differences in the evolution of labour productivity, although once such differences had been overcome these countries returned to the path of growth (Macours and Swinnen 2002).

Finally, Table 2.2 shows that although the growth of labour productivity in different European countries was extremely important, very significant differences persisted 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, in Western European countries labour productivity levels were six times higher than the Central and Eastern European countries (CEEC).

Graph 2. 1. Land productivity in European agriculture (international 1999-2001 prices in dollars per hectare)



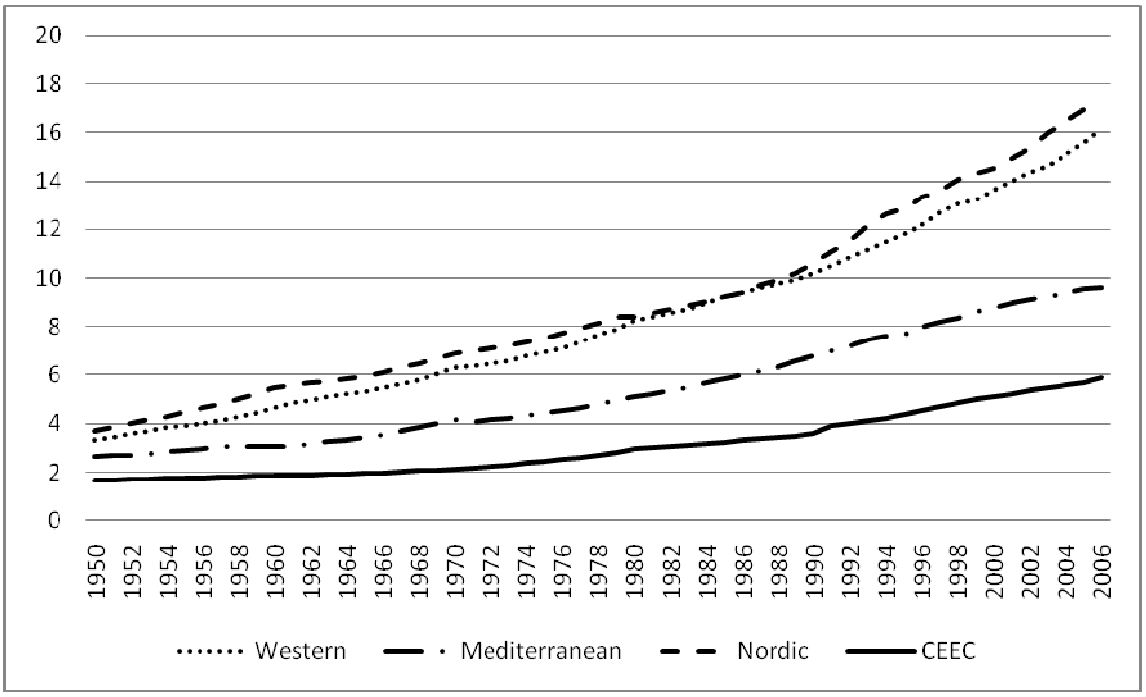
Source: Authors' calculation, from FAOSTAT (2009) and FAO (1948-2004)

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

$\frac{Y}{L} \equiv \frac{A}{L} . \frac{Y}{A}$, where Y is output, A is land and L is labour.

Graph 2.1 (and Table 2.A.1 in the Appendix) show the evolution and levels of productivity per hectare in European agriculture. The highest levels correspond to the countries of Western Europe. Followed at some distance are those of the Mediterranean countries and, especially, those of the Nordic and Central and Eastern European countries. It is reasonable to assume that, to a large degree, these differences could have been due to the distinct agricultural potentialities of the natural resources of the different countries.

Graph 2. 2. Land-labour ratio in European agriculture, 1950-2005



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

Graph 2.2 (and Table 2.A.2 in the Appendix) offer land-labour ratios. They demonstrate that low land-productivity countries, although they tended to increase their land-labour ratios to achieve high labour productivity, did not reach the elevated levels of Western Europe. The Nordic or Spanish land-labour ratios reached the same level as Western countries or Germany, but did not offset their disadvantage in land productivity (Wang et al. 2012). The land-labour ratios of the countries of Central and Eastern Europe and some Mediterranean countries, such as Greece or Portugal, were much lower than the rest of Europe.

2.2.2. Did the labour productivity of European agriculture converge?

From the general increase in agricultural labour productivity, the massive incorporation of new industrial inputs and the biological innovations adopted, it might be assumed that the differences among countries should have fallen. The access to technology capable of generalised application to the entire continent may have fostered convergence. The task is now to determine whether the productivity levels of agricultural labour converged. Table 2.3 shows that the dispersion of

productivity (σ-convergence) increased gradually or was maintained since the 1950s.

Table 2. 3. Dispersion measures of agricultural labour productivity

	Variance of logarithm of labour productivity	Coefficient of variation	Theil	Herfindahl	Gini	Weighted Coefficient of variation
1950	0.6073	0.7223	0.0763	0.0681	0.2689	0.7466
1955	0.6454	0.7119	0.0754	0.0674	0.2686	0.7665
1960	0.6422	0.7449	0.0802	0.0695	0.2511	0.7941
1965	0.6420	0.7487	0.0807	0.0698	0.2563	0.8327
1970	0.7023	0.7937	0.0884	0.0728	0.2580	0.9044
1975	0.6423	0.7804	0.0846	0.0719	0.2459	0.8497
1980	0.6767	0.8041	0.0894	0.0735	0.2583	0.8546
1985	0.6551	0.7822	0.0861	0.0720	0.2610	0.8589
1990	0.6040	0.7482	0.0797	0.0697	0.2644	0.8478
1995	0.6742	0.7981	0.0890	0.0731	0.2877	0.9132
2000	0.6646	0.7692	0.0846	0.0711	0.2891	0.9014
2005	0.5981	0.7593	0.0811	0.0705	0.2764	0.8727

All the figures are calculated using triennial averages, except for 1950. Furthermore, the same number of countries has been maintained, aggregating the individual country data following the dissolution of Yugoslavia and Czechoslovakia. The active agricultural population percentages for each country as a proportion of the total are used as weightings in the weighted coefficient of variation.
Source: Authors' calculation, from FAOSTAT (2009)

Table 2.3 shows that the differences in labour productivity existing within the continent of Europe in 1950 did not decrease until the 1980s. From then on, dispersion displayed small fluctuations or a slight decrease, depending on the measure observed. In the case of the weighted variation coefficient, it is possible to observe similar behaviour to that of the remaining variables, although the change of trend occurred in approximately 1970. Thus, the evolution of the indicators of dispersion in Table 2.3 permits us to affirm that convergence did not exist in labour productivity. The question is now how to explain why such important differences in agricultural productivity levels in Europe have been maintained until today, without convergence among countries. Consequently, we perform an econometric analysis to observe the variables which explain these differences in levels.

2.3. 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 the exit of the agricultural population to industry and services as a consequence of structural change, since agricultural labour is the denominator of this variable. Consequently, either increased production or reduced labour, or a combination of the two, could have raised productivity.

Many causes determine labour productivity levels, from factor endowment and technology to institutions or geography. As both recent economic history and the literature on economic growth show, there exist both proximate and fundamental causes to explain agricultural productivity variations (Crafts 2010). The present study attempts to combine both types of variables.

Proximate causes are the variables included in any production function of the agricultural sector (land and capital), 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 Mundlak et al. 1999, among many others). Machinery and fertilisers have significantly increased their importance in the productive process, in line with agricultural development (Grigg 1992; Federico 2005a). The irrigated land area is another crucial variable, because of its importance in overcoming unfavourable geographical conditions in certain semi-arid 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.

The quality of the labour force is also a variable to be taken into account. In fact, human capital is one of the variables most commonly studied to observe differences in agricultural labour productivity (Hayami and Ruttan 1985; Nguyen 1979).

We also introduce $GDPpc_{it}$ as a measure of the development of the whole economy. There are several studies which take this variable into account to measure differences in agricultural productivity (Van Zanden 1991; Mundlak et al. 1999; Ezcurra et al. 2011). Our understanding is that agricultural labour will be more productive in more developed economies. This is due to the influence of the greater technological level, external to agriculture, on its productivity, or the impact on agricultural efficiency of the availability of better infrastructure and access to markets.

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 the 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. Membership of either the European Union (formerly the European Economic Community) or of the Communist bloc, led by the Soviet Union, have had extremely significant consequences. For some authors these are essential to the understanding of agricultural output in Western and Eastern Europe (Houpt et al. 2010). In addition, international trade openness and subsidies to agriculture are also important dimensions in the development of the institutional framework of the countries analysed (Anderson and Valenzuela, 2008). Some of these latter institutional dimensions overlap with the former (EU and Communist bloc membership) but, given the number of countries involved and the long time span, undoubtedly make the analysis richer.

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 perspectives, involving a partial substitution of market mechanisms by public policies (Federico 2009; Spoerer 2010). The creation of, firstly, a customs union and, secondly, a single, strongly protected,

market has greatly facilitated import substitution and increased trade among members (Pinilla and Serrano 2009). Measures such as export subsidies and minimum prices have provided help to farmers and supported the agricultural sector by trading at prices above international levels (Tracy 1989; Ritson 1997; Andreosso-O'Callaghan 2003; García Delgado and García Grande 2005).

In the Soviet bloc land was collectivised, rationing was introduced and products were requisitioned; essentially, central planning replaced the market economy. Land was either transferred to the state or maintained in private hands. Owners were obliged to join cooperative enterprises while a small part of their production was allowed to remain strictly private. Collective farms increased mechanisation, yet despite lower labour requirements, the collectivised farms "became employers of last resort, providing a meagre subsistence to women and children, the old and the infirm" (Allen 2003, p. 100). The Soviet countries also threatened peasants failing to comply with 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 suffered great structural problems of incentivisation. This was because, following collectivisation, all agricultural workers were guaranteed a minimum income, with little incentive to work harder. Similarly, efficient agricultural policies were lacking, further causing state agriculture to perform beneath its potential (Gregory and Stuart 2001; Allen 2003; Federico 2005a and 2005b; Landau and Tomaszewski 1985).

Support to the agricultural sector through highly diverse measures, such as guaranteed prices, direct income transfers to farmers, purchases of surpluses, structural reform policies or protectionist policies may also have had a significant impact on productivity. On the one hand, subsidies to agriculture, by maintaining or raising the income of farmers above the level they would otherwise have had, may have reduced or impeded a greater growth of productivity. It might therefore have limited or deferred the exit of the labour force from the sector, with a negative effect on productivity. It is also possible that as a consequence of offering more stable perspectives to farmers, such policies would have incentivised capital investment in farms, thereby favouring the improvement of productivity.

International trade openness may also have affected agricultural productivity. It is reasonable to believe that in the more open countries it was necessary to increase competitiveness further, in order to be able to maintain their production in an environment of low protection.

Geography is another fundamental cause of growth. Geographic variables may directly affect agriculture through temperature, altitude, rainfall, sunshine, pestilence and diseases, soil, orography or latitude (Gallup 1998; Grigg 1992; Crosby 1986; Asenso-Okyere et al. 2011). 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. Several studies have underlined that a highly uneven terrain prejudices agriculture and other economic activities (Nunn and Puga 2012; 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 its lack of output is huge unless appropriate measures are taken.

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 polar or tropical, produce the greatest disadvantages.

We now explain the method and variables employed to determine which factors influence agricultural labour productivity. We used a linear function to perform the estimation, including the variables in logarithms[34] and employing the panel data technique. The functional form is based on the production function *translog*[35], to which we have added several institutional and geographical

[34] To make the production function linear and be able to estimate the econometric model we have applied logarithms to it.

[35] The translog production function is a generalization of Cobb-Douglas and is more flexible than the latter. The Cobb-Douglas production function is the same function, assuming βij= 0. The production function used (*translog*) relaxes the implications of additivity and homogeneity (Christensen et al. 1973). Allen (2009) and Pablo-Romero and Gómez Calero (2013) are two recent examples of an estimation of the translog production function.

variables. The sample comprises 32 European countries and annual data for 1950-2006[36].

The equation proposed is:

$$\ln(\text{product}_{it}) = \alpha_i \sum_{i=1}^{n} \beta_i \ln(x_{it})\, 0.5 \sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln(x_{it}) \ln(x_{jt}) + \alpha_1 \ln(\text{khumans}_{it}) + \alpha_2 \ln(\text{GDPpc}_{it})$$
$$+ \alpha_3 \text{communist}_{it} + \alpha_4 \text{EU}_{it} + \alpha_5 \text{subsidies}_{it} + \alpha_6 \text{open}_{it} + \alpha_7 \text{geo}_i + + \gamma_1 z_{1it} + \cdots$$
$$+ \gamma_{T-1} z_{T-1it} + u_{it};\ \ \beta_{ij} = \beta_{ji}\,; x = A, L, F, M, I;\ i = 1, \ldots, N;\ t = 1, \ldots, T$$

The endogenous variable *Productit* 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[37]. The correct measurement of the labour factor would be of hours worked, but data for this variable are not available[38].

The *x* matrices 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) or calculated by ourselves, based on these sources. We divided all the variables forming the x matrix by agricultural labour. *Landit* (A) is the area of arable land and permanent crops. *Livestockit* (L) is the stock of live animals, calculated using the weightings of Hayami and Ruttan (1985). *Fertilizerit* (F) is the sum of the consumption of potassium, phosphate and nitrogen fertilisers. *Machineryit* (M) is the number of tractors. *Irrigationit* (I) is the area per worker equipped for irrigation[39].

[36] See Appendix.
[37] See Appendix.
[38] 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 time sample. Furthermore, the calculation of this variable takes *ad hoc* assumptions into account. Therefore, in the present study we have preferred to maintain the active agricultural population as the relevant variable. Gollin et al. (2014b) have investigated in depth the possible effects of an inadequate estimation of labour productivity in agriculture. Their conclusion is that even after correcting the errors in the estimation, there persist enormous differences among countries.
[39] Our variables are measured in dollars, in the case of production and input quantities. We have used a primal analysis. Concerning the possibility of performing the dual analysis with prices, Mundlak (2001, 77) sees several possible reasons for the poor performance of prices, due mainly to the fact that duality is a micro theory, and therefore applications with macro data present additional problems.

The measure of human capital shows the Gross Enrolment Ratio in secondary education (*khumans*$_{it}$). We have calculated this ratio using statistics from the World Development Indicators (2011) and Mitchell (2007)[40].

We obtain GDP per capita from Maddison (2010), expressed in 1990 International Geary-Khamis dollars[41].

Four variables proxy the effect of institutions on productivity. *Comunistit* is a dummy which takes the value of 0 if the country does not have a centrally planned economy and 1 otherwise. *EU*$_{it}$ is another dummy which takes the value of 0 if the country does not belong to the EU (formerly the EEC) and 1 otherwise. *Subsidies*$_{it}$ is a qualitative variable that takes into account whether economic policy supported the agricultural sector (value 1) or not (value 0). This last variable is from the Anderson and Valenzuela (2008) database. We took into account the Nominal Rate of Assistance (NRA), that is to say the change in income after price support and direct income support as a proportion of income in the non-policy situation. We assume a policy of support if the NRA in the agricultural sector is greater than 0.2, to take into account strong support for agriculture[42]. Finally, *Openess*$_{it}$ is a qualitative variable which takes the value of 1 when a country has an open economy and 0 when it is closed. To perform this classification for each year we based ourselves on Sachs and Warner (1995) and their classification of countries into open or closed economies. For those countries or years for which these authors do not offer data, we have used, complementarily, the World Development Indicators and Maddison (1991).

Physical geography, *geo*$_i$, is measured through the percentage of the area of each country in distinct bioclimatic regions (Western, Mediterranean and polar). A bioclimatic zone or biome is a zone of the planet with a common climate, vegetation and fauna. Latitude, temperature, precipitation and altitude define the basic characteristics of the climate of each zone (CIESIN 2007). The estimation omits the so-called western biome, to observe the disadvantage to the other two biomes.

[40] See Appendix.
[41] For more details, see Appendix
[42] See Appendix.

The variables represented by *z* are the time dummies included in the econometric model. The last year is omitted in these time dummies, to avoid perfect multicollinearity, and estimated as base.

Table 2. 4. 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	5.64	7.39	9.59	11.14
	St. Dev.	1.42	2.08	2.70	3.43	4.39	6.01	7.30
Fertilizers per worker	Mean	0.20	0.50	1.12	1.57	1.47	1.65	1.95
	St. Dev.	0.23	0.48	0.89	1.13	1.28	1.38	1.47
Tractors per worker	Mean	0.03	0.14	0.30	0.48	0.62	0.75	0.87
	St. Dev.	0.06	0.14	0.25	0.36	0.43	0.50	0.60
Live animals per worker	Mean	3.32	5.12	7.43	10.16	12.51	15.18	16.48
	St. Dev.	2.53	4.32	6.74	9.01	11.45	14.58	15.28
Irrigation (ha.) per worker	Mean	0.12	0.17	0.34	0.59	0.89	1.23	1.35
	St. Dev.	0.16	0.21	0.34	0.60	0.86	1.17	1.41
Human capital (secondary)	Mean	32.00	57.93	75.12	85.31	96.11	102.39	99.81
	St. Dev.	17.53	24.19	16.06	13.29	13.75	19.04	11.10
GDPpc	Mean	3,774	5,823	8,588	10,437	12,031	14,709	16,402
	St. Dev.	2,190	3,005	3,932	4,468	6,085	7,252	7,595
Institutions (number of countries)	Communist	7	8	8	8	2	1	0
	EU	0	5	5	9	11	14	19
	Subsidies	11	13	12	14	17	20	17
	Open	5	15	16	16	24	28	28

Source: Authors' calculation, from FAOSTAT (2009) and FAO (1948-2004).
The data are triennial averages, except for 1950 and the data for institutions. Albania is omitted in 1950 because of the non-availability of data. To construct this table, we maintain the same number of countries, except for secondary human capital after 1992, since we cannot aggregate the gross enrolment ratio.

Table 2.4 shows the mean and standard deviation for the European continent of the explanatory variables used in the econometric model and the number of countries forming the institutional groups. Firstly, capital endowment per worker (whether in machinery, fertilisers, irrigation or animals) has increased very significantly. The increase in land per worker was also remarkable, rising by 400%. Lastly, the standard deviation of the use per worker of these factors tended to increase, except for human capital at the secondary level of education.

We used the panel data method to obtain the final results; it improves the efficiency of the estimators, since it accumulates more information on variations in

the data, controls for individual country heterogeneity and identifies and measures effects which cross-section analyses do not detect. Moreover, it reduces the problem of omitted variables (Baltagi 2005; Hsiao 1999). Consequently, the panel data technique is more precise than its cross-section counterparts.

2.4. Results

We obtained the econometric results by an OLS estimation with pooled data, and also by random effects and fixed effects, to check which estimation was optimal. We used the Breusch-Pagan LM test and F-test (Greene 1997) to choose between the OLS and random and fixed effects estimations respectively. In both of them we rejected the null hypothesis, which corresponds to an OLS estimation. As a result, the OLS estimation is not included in the results table.

We tackled two relatively common econometric problems, heteroscedasticity and autocorrelation, by the Wald (Greene 1997) and Wooldridge tests (Wooldridge 2002), respectively. We rejected the null hypothesis of homoscedasticity, but the p-value of the autocorrelation test is 0.4670, and thus we did not reject the null hypothesis of non-autocorrelation.

The first column in Table 2.5 gives the random effects estimation. Furthermore, the Hausman test reveals that the differences between estimators are significant, when comparing columns (1) against the fixed effects estimation (2). This test has a p-value which is null or lower than 0.05, and thus the best estimation is that of fixed effects (column 2). The inconvenience of this procedure is that it omits those geographical variables which are constant over time.

Table 2. 5. Econometric results

	RE	FE	PCSE	G2SLS (IV)
Land (a)	-.0957	.4866***	.6576***	.5309***
	.0797	.1003	.0959	.0283
Livestock (l)	.0800***	.0464***	.0512***	.0063***
	.0059	.0042	.0035	.0011
Fertilizer (f)	.2223***	.1655***	.0685**	.1033***
	.0593	.0481	.0308	.0109
Machinery (m)	.3502***	.0775**	.1372***	.0853***
	.0349	.0308	.0413	.0107

Irrigation (i)	.1050***	.0948***	.0595**	.0185***
	.0206	.0256	.0244	.0069
Human Capital	.0573***	.1371***	.0821***	.1519***
	.0056	.0146	.0105	.0161
Communist	-.1675***	-.1058***	-.1187***	-.1290***
	.0203	.0209	.0184	.0191
EU	.0900***	.0538***	.0580***	.0225*
	.0170	.0120	.0107	.0135
Subsidies	-.0655***	-.0323***	-.0295**	-.0134
	.0181	.0125	.0125	.0142
GDPpc	.2637***	.1191***	.1956***	.2378***
	.0187	.0307	.0259	.0294
βaa	.1738***	-.0379	-.0907**	-
	.0369	.0449	.0448	
βff	-.0464**	-.0462***	-.0425***	-
	.0217	.0148	.0127	
βmm	.0133**	-.0021	-.0034	-
	.0066	.0055	.0053	
βll	.0002	-.0006***	-.0006***	-
	.0002	.0001	.0001	
βii	.0121***	.0218***	.0205***	-
	.0025	.0039	.0038	
βam	-.1152***	-.0238**	-.0171	-
	.0132	.0119	.0120	
βaf	.0313	-.0024	.0042	-
	.0213	.0155	.0138	
βal	-.0231***	-.0047**	-.0060***	-
	.0023	.0019	.0017	
βmf	-.0703***	-.0417***	-.0464***	-
	.0148	.0102	.0098	
βml	.0082***	.0024	.0018	-
	.0020	.0015	.0015	
βfl	-.0028	.0007	.0006	-
	.0021	.0014	.0012	
βia	-.0164**	-.0196*	.0041	-
	.0078	.0105	.0096	
βim	.0107***	-.0053*	-.0080***	-
	.0033	.0029	.0030	
βif	-.0015	-.0050	-.0071**	-
	.0060	.0041	.0036	
βil	.0021***	.0019***	.0019***	-
	.0007	.0005	.0004	
Parbpolar	-.5736***	-	-	-
	.0254			
Parbmediter	-.0138	-	-	-
	.0256			
Constant	6.6418***	7.9223***	.0002	7.0712***
	.2161	.3845	.0024	.3522
R^2 within	0.9669	0.9795	0.8982	0.9643
No. observations	1,411	1,411	1,411	1,347

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. The letters in parentheses, close to the name of the variables, correspond to the sub-index in the group of β. All the variables are in logarithms, except *parbpolar*, *parbmediter*, *comunist*, *eu* and *subsidies*. We have not included in the table the elevated number of time dummies in the model. The coefficients and their standard deviations are available on request. The value of R^2 within the PCSE estimation corresponds to R^2.

Heteroscedasticity can be resolved using the estimation in column 3 (Panel Corrected Standard Error). We chose the PCSE estimation, following Beck and Katz (1995), as they compare the standard errors of the PCSE with FGLS (Feasible Generalized Least Squares). The PCSE standard errors are more precise than the other estimations.

The results of the econometric model show, firstly, that intensity in the use of productive factors is decisive in explaining the differences in the productivity levels of European agriculture in the second half of the twentieth century. Especially notable is the importance of the land per agricultural worker variable (*land*), with a significant coefficient and the expected sign. The elasticity of this variable would be 0.49[43]. That is to say, an increase of 1% in this variable would increase productivity by 0.49%. This underlines that the increase in the land/labour ratio was a powerful determinant of labour productivity differences. In the second half of the twentieth century a highly varied and intensive process of rural exodus in Europe took place (Collantes and Pinilla 2011). In short, and as Table 2.1 shows, the cultivated land area fell, but by much less than the labour force. As a result, one of the driving forces behind agricultural productivity growth came from outside agriculture itself. The culmination of industrialisation in many countries or its rapid advance in others, together with the growth of the services sector, involved a formidable rural exodus. This reduced, for the first time in the majority of European countries, not only the share of agricultural workers in the total active population, but also their numbers. Agricultural productivity 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 and exploitation of the

[43] To calculate the elasticities in a translog production function, it is necessary to combine the value of the coefficient of each variable with the coefficients of its interactions. Pablo-Romero and Gómez-Calero (2013: 79) give the concrete formula.

technology available to intensively mechanize production (Federico 2005a; Fennell 1997). Modern agriculture was thus able to achieve certain economies of scale, replacing workers by machinery.

Naturally, 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, meaning that workers had to be more efficient. Machinery was from this perspective crucial, and thus the positive sign and significance for tractors per worker are unsurprising in explaining differences in labour productivity (an elasticity of 0.09). The same is true of livestock units per worker (an elasticity of 0.03). New processes in livestock breeding and dairy, poultry, pork and beef production meant the industrialisation of a previously highly labour-intensive activity, one in which substantial economies of scale were achieved. New livestock breeding methods permitted its disassociation from the soil and the ecological limits for its development in countries with less favourable natural conditions. Briefly, it is also natural for the use of fertilisers to show the expected positive sign and be significant; their contribution to the raising of productivity was considerable (an elasticity of 0.13).

Irrigation is another crucial variable in explaining the differences in agricultural labour productivity, since it has a positive sign and is significant (an elasticity of 0.05). Irrigation meant improving yields in arid or semiarid regions (approximately two thirds of irrigated lands in Europe were concentrated in France and the Mediterranean countries). In Spain, for example, one of the driest countries in Europe, irrigated farming accounted for less than one third of the agricultural land area, but for over two thirds of crop production (Cazcarro et al., forthcoming).

The diffusion of technology throughout agriculture, principally through the incorporation of inputs from the industrial sector, is key to understanding both the levels and growth of labour productivity. The diffusion and adoption of the new technologies followed distinct paths in the European countries. In the countries with centrally planned economies there were clear problems of efficiency in their use, and similarly a certain lag in the adoption of state-of-the-art technologies (Gregory and Stuart 2001, Allen 2003). In the market economies, the boost to

public research into R&D and structural reform policies, with the aim of achieving larger and more highly capitalized farms, stimulated technological development (Neal 2007, Houpt et al. 2010). Whatever the case, its diffusion in the agricultural sector was performed unequally, given the biased and localized nature of technological change (Hayami and Ruttan, 1985; Acemoglu, forthcoming).

The variables β_{ij}, listed in Table 2.5, are the products of the first five inputs. The negative sign in the quadratic coefficients for land, fertilisers and livestock show the decreasing returns of scale for these inputs. In addition, machinery and fertilisers are substitutes, owing to the negative sign of their crossed coefficient[44].

The positive and significant coefficient of the Gross Enrolment Ratio in secondary education shows that the improvement in education in European countries also had a substantial effect upon agricultural productivity. Thus, the distinct educational levels reached are also important in explaining differences in agricultural labour productivity.[45]. A secondary level of education permits the use of more advanced techniques.

The role played by the development of the whole economy is also considerable. The variable $GDPpc_{it}$ is significant and positively related to agricultural labour productivity. This influence means that the agricultural sector is not alien to the economy as a whole, and that the degree of development of the economy is crucial to understanding differences in agricultural labour productivity. Good infrastructure facilitated better access to markets and, in general, a reduction of transaction costs, as well as better integration between the agricultural sector and the agrifood industry. But the high level of economic development also facilitated improved access to credit, the development of agricultural extension and the expansion of general purpose technologies with an impact on agricultural productivity. In summary, all these factors favoured the faster growth of agricultural productivity, thanks to the advantage of integration of the sector into an economy of high incomes and technological capacities.

[44]Allen (2009, p.425) has explained, regarding these estimated translog parameter values, that "their economic significance lies in their implications for elasticities of substitution".
[45] We attempted 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 econometric model also clearly shows that institutional variables help to understand the differences between distinct levels of agricultural productivity. Membership of either the EU or the Communist bloc are significant at 1% and show the expected sign (positive for the EU and negative for the centrally planned economies). Policies of subsidies to agriculture also affected productivity. In this case, the negative sign underlines that they depressed it. Finally, openness is not significant, and thus is not included in the final model. Its lack of effect upon productivity could be due to the fact that this variable represents the opening of the economy as a whole, and not exclusively that of the agricultural sector. In the most developed countries there coincided in that period a strong opening of the industrial sector with high agricultural protectionism. This divergence in sectorial commercial policies may explain the above mentioned lack of statistical significance.

The institutional framework defined by a centrally planned economy implies that this system prejudiced productivity in various ways, for example by land collectivisation and product requisition, the control of production and prices by planners, threats to peasants failing to comply with state plans, 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 for exports to third countries, causing prices to exceed international market prices (García Delgado and García Grande 2005; Serrano and Pinilla 2011). On the one hand, it is consequently reasonable to assume that this policy encouraged production, providing security, stability and improved incomes for European farmers, who were thus able to adopt the new technologies available at an impressive rhythm. On the other hand, the European Union policy of price

support meant that workforce could be retained in the agricultural sector, lowering productivity.

The results of the model, with a negative sign of the variable *Subsidiesit*, makes it clear that the policies of the transfer of income to agriculture, by raising the revenue of farmers, permitted the permanence in this activity of a volume of labour power greater than that which would have existed otherwise. Logically, this affected productivity negatively. Nevertheless, it is necessary to make a considerable number of assumptions for the calculation of this variable, given the scarcity of the existing data, requiring us to be very cautious with their interpretation (see the Appendix for a detailed explanation of its calculation).

With regard to the effect of physical geography, although the final model did not permit the inclusion of the variable used to estimate its impact, we do have some indications regarding a possible relevant influence. The results obtained in the first estimation of random effects (column 1 in Table 2.5) show a significant disadvantage for the polar bioclimatic zone (*parbpolar*) compared to the western zone, which is the reference. Although the coefficient of belonging to the Mediterranean zone (*parbmediter*) displays the negative sign expected, it is not significant. However, we previously confirmed that the irrigated land area per worker was significant and had a positive influence upon productivity. This shows that the enormous development of hydraulic works in the driest countries permitted them to compensate for their unfavourable environmental conditions. Long hours of sunshine, typical of the Mediterranean countries, permitted (with sufficient water) the development of intensive crops of high value and strong demand.

Furthermore, to make our estimation more robust and to avoid possible reverse causality, we estimate an Instrumental Variables regression without the interactions of the translog function in column 4. To perform these estimations we use as instruments the following lagged variables (for two periods): land, livestock, irrigation, machinery, fertilisers, human capital and GDP per capita[46]. In the last column (G2SLS IV regression) our estimations of PCSE (column 3) are clearly

[46] The introduction of even bigger lags would avoid in greater measure the problems of reverse causality. However, as is logical, it is difficult to expect significant effects on productivity from changes in the use of factors in very distant periods.

robust, because the coefficients and significance do not change, with the exception of the variable *Subsidies*.

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 pesticides and herbicides, raised agricultural productivity; this omission could lead to the overrating of the importance of the variables that we have included in our model.

5. Dynamic specification: a further step

We have shown in Section 2.2 that differences among the European levels of agricultural labour productivity did not decrease after 1950, as sigma convergence does not exist. Nevertheless, we believe it is interesting to investigate whether the different rhythms of the growth in labour productivity were conditioned by their initial level; that is to say, we have attempted to verify the existence of unconditional beta convergence[47]. To do this, we have performed an analysis with a dynamic specification, namely an analysis with the growth of agricultural labour productivity as the endogenous variable and the initial period of the endogenous variable as an explanatory variable. The dependent variable is the quinquennial logarithmic growth rates of agricultural labour productivity[48]. We performed this estimation using panel data methodology and a linear regression. The first column of Table 2.6 offers our results. The coefficient is negative and significant at 10%, meaning that the initial level of labour productivity affected the growth of this variable, and thus unconditional convergence existed. The speed of convergence was 1.23%.

This analysis involves accepting the hypothesis that the technologies, environments or institutions of all countries are similar, which is clearly

[47] For some authors, if sigma convergence does not exist, there is no interest in investigating the existence of beta convergence (Quah, 1993). However, for others, the study of how far the initial levels condition subsequent growth (beta convergence) is interesting in itself (Sala-i-Martin, 1994).
[48]We performed the same estimation with decennial growth rates. The principal results did not change.

unrealistic, since it would imply that all countries display the same stationary state. Consequently, we have also tried to propose a model to which we add as explanatory variables (at the beginning of each five-year period) the initial level of those used in the model from the previous section. They are in logarithms. Thus, we can test for the existence of conditional convergence. We follow the same estimation procedure as in the previous section. The equation used for the estimation is:

$$\ln(Product_{it}) - \ln(product_{it-1}) = \alpha_i + \beta \ln(product_{it-1}) + \\ + \sum_{i=1}^{n} \gamma_i \ln(x_{it-1}) + \delta_1 \ln(khumans_{it-1}) + \delta_2 ln(GDPpc_{it-1}) \\ + \delta_3 communist_{it-1} + \delta_4 EU_{it-1} + \delta_5 subsidies_{it-1} + \delta_6 geo_i + u_{it}$$

The results in Table 2.6 show that convergence becomes stronger and notably more rapid (6.9%) if we include the explanatory variables for the initial period[49]. In explaining the growth of agricultural labour productivity, the initial level of productivity is negative and significant; that is to say, the lower the initial level of productivity the greater is its growth. The results confirm the existence of different stationary states towards which countries converge, depending on their initial technologies, environments and institutions (Barro and Sala-i-Martin 1992). The variables which determine the different stationary states are the land-labour ratio and machinery per worker. These variables are determinant in explaining the growth of agricultural labour productivity, as they are positive and significant. Thus, the availability of more highly mechanized agriculture and a higher land-labour ratio at the outset facilitate greater agricultural productivity growth. In summary, the use of machinery on large farms helps certain economies of scale to be achieved. This result confirms the argument proposed by O'Brien and Prados (1992, 534), which signals that "by comparison the long-term growth of most other continental economies seems constrained by a historical legacy of higher population densities coupled with unfavourable land-labour ratios".

If we include time dummies in the dynamic specification, the principal results do not change, although the percentage of polar land becomes significant.

[49] The Hausman test recommends a fixed effects estimation. Subsequently, we performed the PCSE estimation (column 4).

This could reinforce the influence of geography on agricultural productivity. Besides, the non-significance of the Mediterranean area may show that certain geographical obstacles can be solved by investment in irrigation.

Table 2. 6. Results of dynamic specification

	PCSE	RE	FE	PCSE	RE robust
Productivity	-.0123*	-.0446***	-.0839***	-.0691***	-.0435***
	.0072	.0133	.0161	.0163	.0146
Land	-	.0319***	.0636***	.0628***	.0305**
		.0111	.0176	.0197	.0149
Livestock	-	.0001	.0001	-.0001	-.0001
		.0006	.0006	.0004	.0004
Fertilisers	-	-.0001	-.0001	.0017	.0033
		.0053	.0054	.0042	.0048
Machinery	-	.0126***	.0173***	.0235***	.0178**
		.0042	.0052	.0078	.0084
Irrigation	-	-.0045*	-.0044	-.0053	-.0025
		.0026	.0040	.0030	.0024
GDPpc	-	.0028	-.0067	-.0034	.0092
		.0115	.0146	.0162	.0146
Human capital	-	.0018	.0149*	-.0049	.0064
		.0043	.0088	.0057	.0051
Communist	-	-.0033	.0050	.0147	-.0025
		.0101	.0112	.0133	.0159
EU	-	-.0042	-.0013	-.0012	-.0037
		.0074	.0075	.0067	.0087
Subsidies	-	-.0025	-.0089	-.0098	-.0084
		.0074	.0075	.0072	.0110
Parbpolar	-	-.0404	-	-	-.0567***
		.0250			.0195
Parbmediter	-	.0005	-	-	.0121
		.0224			.0229
Constant	.0000	.3839***	.8880***	-.0002	.3487**
	.0019	.1327	.2168	.0017	.1479
Time dummies	No	No	No	No	Yes
R^2 within	0.0145	0.1588	0.1833	0.1423	0.1866
No. observations	303	303	303	303	303

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. All the variables are in logarithms, except *parbpolar*, *parbmediter*, *communist*, *eu* and *subsidies*. We have not included in the table the high number of time dummies in the model. The coefficients and their standard deviations are available on request. The value of R^2 within the PCSE estimation corresponds to R^2.

2.6. Conclusions

In recent decades the debate regarding the causes of long-term growth in agriculture has been one of the most intense and lively in economics. Together with the variables which have usually been taken into account, the so-called proximate causes, this debate has broadened its scope by considering further causes, termed fundamental, which are key to explaining such growth. Economic historians have played an important role in the debate, especially if we bear in mind that the contributions of Douglas North and others have been decisive in introducing the role of institutions into the debate regarding growth.

The European economy grew at an extraordinarily fast rate between 1950 and 1973. The oil crisis meant a sharp halt to this trajectory which, although it would restart from the 1980s onwards, would not recover the high rates of the Golden Age. Especially in the explanation of the Golden Age, extensive literature has discussed its causes. In general terms, economic historians, in distinction to agricultural economists, have not paid excessive attention to events in the agricultural sector, despite the importance of its changes. Furthermore, the discussion regarding the reasons stimulating them has not been tackled from a long-term perspective and for the European continent as a whole.

The present study is aimed at filling this void. Our contribution has attempted to connect to the more general discussion regarding the causes of economic growth. In the same way as in the more general debate regarding growth in the Golden Age, technological, institutional, structural change or post-war shock hypotheses have been counterposed; we believe that agricultural growth must be explained by a combination of proximate and fundamental causes. In summary, this requires analysing the income gap which exists among the diverse countries (Gollin et al., 2014 a).

In the last fifty years agriculture has undergone far-reaching transformations, causing the greatest increase in labour productivity in the last two centuries. Agricultural production more than doubled but utilized only twenty per cent of the workers in 2005 compared to 1950. However, although in Europe in this same period productivity growth was extremely rapid, the differences among countries were maintained. The great dispersion of productivities existing

in 1950 has not been reduced in the framework of a rapid and generalised increase of such productivities in all countries.

This study has shown that in addition to the variables normally included in a production function, or proximate causes of growth, the so-called fundamental causes also play an important role in explaining differences in agricultural labour productivity.

Among the proximate causes, 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. These results coincide with those of other studies, whether for Europe in earlier dates or for comparisons with other groups of countries (Sharma et al. 1990; Van Zanden 1991; O'Brien and Prados 1992; Gollin et al., 2014 a).

The increase in land endowment per worker was accompanied by extremely intensive mechanization. Differential capital endowment per worker, fertilisers and, above all, tractors and harvesters, were thus essential. 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 differences did not decrease and convergence did not exist.

These results enrich the debate on the relationship between economic growth and agricultural transformation. The acceleration of economic growth and the advanced stage of demographic transition generated a strong demand for labour in industry and the service sector (Temin 2002). 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 were therefore conditioned by distinct levels of development in different countries.

In turn, institutions also affected differences in productivity. We detected a direct relation between membership of the EU and the productivity of agricultural

labour. By contrast, this relationship is reversed in the case of Communist bloc membership. Policies of support for agriculture negatively affected agricultural productivity, as they retained active population which otherwise would have abandoned the sector. This demonstrates the importance of the institutional framework in explaining differences in economic growth, and in our case 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[50]. Given the contradiction between the boost to productivity of membership of the EU and the negative effect of support for agriculture, subsidising it as in the case of the CAP, it is reasonable to believe that the stimulation of productivity was above all the result of the existence of an integrated market, with the progressive abolition of trade barriers among members. Access to a large market, with the possibility of obtaining certain economies of scale, must have favoured the growth of productivity, stimulating technological improvement. Furthermore, policies of structural reforms could have played an important role, as they made the achievement of economies of scale and the modernization of farms possible.

The impact of geography on productivity differences, important in traditional agriculture, appears in the second half of the twentieth century, especially through cold weather and aridity. Furthermore, this latter impact must have been reduced by the extension of irrigated farming to the extremely arid Mediterranean countries, whose high insolation and sufficient water 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 twentieth century (Pinilla and Ayuda 2010). Lastly, the obstacle for the Scandinavian countries of their extreme climate was not compensated for by the new agricultural technologies employed, which would partly explain the disappointing performance of such countries in terms of labour productivity.

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

The dynamic model, finally, helps to understand the determinants of agricultural labour productivity growth. The existence of different initial conditions among countries also implies that there are different stationary states. The availability of more highly mechanized agriculture and a higher land-labour ratio at the outset facilitate greater agricultural productivity growth.

Appendix

Countries included in the tables and econometric model:

The econometric model, as an unbalanced panel, includes those countries really existing for each year. 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, the Netherlands, Poland, Portugal, Romania, Sweden, Switzerland, the United Kingdom and Yugoslavia. From 1990 onward only the Federal Republic of Germany appears, as the consequence of German reunification. From 1991 onwards, Yugoslavia has been replaced by Bosnia-Herzegovina, Croatia, Serbia-Montenegro, Slovenia and Macedonia. In 1992 Czechoslovakia was divided into Slovakia and the Czech Republic.

We have obtained net production (see below "Calculation of the variables") since 1950 for all the above 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, we have aggregated data from all the above mentioned countries in the respective years until 1991 and 1992. From 1991, we have been taken into account the countries emerging from Yugoslavia. Since 1992, the former Czechoslovakia has been two countries.

Tables 2 and 3 and graphs 1 and 2 show that after 1990 the data continue for 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. We have performed the convergence calculations identically.

The data from Albania in table 2 and graphs 1 and 2 supposed that land and labour data was the same than in 1961. We have estimated the data for production in 1950 supposing that production evolved equal that the main Albanian crops offered by FAO (1948-2004). To obtain the production along 1950s, we have interpolated.

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 followed 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 obtained for all the above countries the 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 measure their net production 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 agricultural production for each country; the sources are Berend and Ranki (1985) and Landau and Tomaszewski (1985) respectively. We have taken as reference net production in 1961 and assumed that the evolution of agricultural production in the 1950 followed the trend appearing in these indexes. For Bulgaria, Czechoslovakia, the German Democratic Republic and Romania, we obtained production in quantities during the 1950s from FAO (1948-2004). We have calculated production in 1999-2001 dollars using prices from FAOSTAT (2009). Such calculations have 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 for the 1950s taking net production in 1961 as reference.

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 between 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 to net annual production, as provided by FAOSTAT.

Active population: We obtained the total active agricultural population from FAOSTAT (2009), from the estimations made in 2006 and 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, appear in FAOSTAT (2009) and we have disaggregated them 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. We used the total active population for each of the two countries for those years to linearly interpolate between these values to obtain an annual series.

In the case of Romania, we needed to reconstruct the active population in agriculture because data prior to 1956 are not available. We assumed 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).

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

Machinery: We measured this variable by tractors, as compiled by FAOSTAT (2009). The data for the 1950s and the two German republics come from FAO (1948-2004).

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

Human capital: The variable is Gross Enrolment Ratio in secondary education. To calculate this variable we have employed data from the World Development Indicators (hereafter WDI, 2011) and Mitchell (2007). The data provided by Mitchell (2007) are the following variables: the number of pupils in secondary education and national population by sex and age groups. To obtain the annual series we had to perform the necessary interpolations. The majority of countries have data available in WDI (2011), except for the 1960s (the database does not provide the variables for this decade), which can however be calculated

using the data supplied by Mitchell (2007). Nevertheless, there are several calculations necessary for some countries, which were exceptions.

We have calculated figures for the case of Albania, with its lack of data from 1976 onwards for secondary education, using the annual growth rates between 1976 and 1980, assuming this growth was constant from 1961 to 1976.

For the period between 1970 and 1992 we have 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 their evolution come from Mitchell (2007).

The case of the German Democratic Republic is trickier. To rebuild the secondary education variable, we assume that in 1950 this country had the same gross enrolment ratio than the German Federal Republic. For the rest of the period, we assume that this country displayed the same evolution as the other Communist countries.

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. For Croatia, Bosnia and Serbia we have assumed that they displayed the same figure for the first year of the sample as Slovenia in 1991 in secondary education. We then interpolated to obtain the annual sample.

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

The data from Mitchell (2007) for Bulgaria and Poland present some important gaps, due to different changes in the consideration of pupils in secondary education. In the case of Bulgaria we assumed that in the period of 1950-1970 this country followed the same evolution as Romania. In the Polish case, we did not take into account the data from Mitchell (2007) for the 1960s. To correct this, we performed a linear interpolation for this decade.

GDP per capita: We had to calculate the GDP per capita for the German Democratic Republic and for the German Federal Republic. We used for that the population data of Sleifer (2006, 53 and 54) and, additionally, the GDP index for

GDR (Sleifer 2006, 193). We also use Maddison (1995 and 2010). We calculate the percentage of each republic's GDP over the reunified Germany in 1990 according to Maddison (1995). With these percentages, we calculate both republics' GDP in 1990, taking into account the German GDP calculated by Maddison (2010). Thus, we obtain the GDR's GDP by assuming this variable follows the Sleifer (2006) index. Dividing this series by the GDR population (Sleifer 2006), we have obtained the GDP per capita for the GDR. Then, we determine the GFR's GDP per capita as the quotient of two substractions. In the first one, the reunified Germany's GDP is subtracted from the GDR's GDP. Finally, the same is performed for population. We thereby obtain GDP per capita for the German Federal Republic.

Subsidies: Our data come from Anderson and Valenzuela's (2008) database, which begins in 1956. For the countries included therein, we have assumed that aid to agriculture was the same between 1951-55 and 1956.

The principal problems of the Anderson and Valenzuela (2008) database are the lack of some countries or some years for several countries; some countries, such as Belgium, Luxembourg, Albania, Bosnia-Herzegovina, Croatia, Czechoslovakia, Macedonia, Serbia-Montenegro and Yugoslavia, do not appear. This has required us to make a series of assumptions, with a certain risk on occasions, for which we have based ourselves on the studies cited in the bibliography.

For Belgium-Luxembourg, we have assumed that they followed the evolution of the Netherlands. For the other countries from Eastern Europe, we have assumed that they did not assist agriculture.

Neither do the German republics appear. We have assumed that the data which appear for Germany in this database since 1956 correspond to the German Federal Republic. We have hypothesized that the German Democratic Republic, like the other former Communist countries, did not assist the agricultural sector.

Other countries appear in this database, but their first datum is post-1956. These countries could be divided in two groups. On the one hand, the data for Norway and Switzerland begin in 1979. We have assumed that they maintained the policy of strong support for agriculture prior to that year.

On the other hand, the data for Bulgaria, Hungary and Romania begin subsequent to the collapse of the Communist bloc. We have assumed that before this implosion these countries did not subsidize their agricultural sectors.

Bioclimatic zones: The western bioclimatic zone (the reference) formed by the bioclimatic zone of wide leaf forests, mixed forests and temperate conifer forests, is 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).

Data tables of Graph 2.1 and Graph 2.2

Table 2.A.1 Land productivity in European agriculture (international 1999-2001 prices in dollars per hectare)

	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	536	825	760	681	936	1,257	1,523
Spain	325	447	572	738	909	1,166	1,207
Mediterranean Europe	**538**	**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	399	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	**413**	**551**	**727**	**888**	**834**	**800**	**899**
Europe	**615**	**854**	**1,098**	**1,337**	**1,416**	**1,488**	**1,529**

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), except for 1950.
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

Table 2.A.2. 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	2.42	3.58	4.55	5.47	-	-	-
Austria	1.66	2.37	3.73	5.17	5.80	7.37	8.49
Belgium-Luxembourg	2.65	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	3.34	5.15	6.69	10.20	15.53	22.26	27.17
Ireland	2.53	4.10	4.67	4.65	5.77	6.74	7.34
Netherlands	1.56	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	5.98	7.86	9.89	9.95	10.66	11.12	11.85
Western Europe	**3.32**	**4.95**	**6.45**	**8.55**	**10.84**	**13.58**	**15.58**
Greece	2.52	2.21	2.82	3.29	4.31	4.72	5.15
Italy	1.93	2.62	3.26	4.67	6.22	9.00	9.98
Portugal	2.26	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.	**2.65**	**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	0.90	0.92	1.01	0.92	0.98	1.13	1.11
Bulgaria	1.47	2.03	3.17	4.65	9.06	16.08	19.42
Czechoslovakia	2.49	3.41	4.51	4.89	6.05	7.26	8.01
Hungary	2.67	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	1.18	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	**1.65**	**1.87**	**2.24**	**3.04**	**4.00**	**5.09**	**5.72**
Europe	**2.26**	**2.78**	**3.47**	**4.61**	**6.02**	**7.58**	**8.56**

The data for the groups of countries are weighted averages. All the figures are calculated using triennial averages. We have assumed that the data of labour for Albania in 1950 is the same than 1961.
Source: Authors' elaboration, from FAOSTAT (2009) and FAO (1948-2004)

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Chapter 3. How important are the fundamental causes of economic growth? An analysis of the total factor productivity of European agriculture, 1950-2005

3.1. Introduction

There is a remarkable and lively debate in the economic literature about the causes of modern economic growth. Traditionally, analysts have sought to explain this growth through certain variables, such as physical and human capital, and technology. However, the fundamental causes have attained an important role in the explanation of income differentials from one country to another, in which the underlying factors are institutions, geography, trade, and culture, among others (Acemoglu et al. 2001 and 2005; Frankel and Rommer 1999; Sachs and Warner 1995; Sachs 2000). Economic historians should be involved in this debate, due to their expertise in long-term analysis.

The aim of this work is to discover the fundamental causes of agricultural productivity growth. To do this, we analyse the agricultural Total Factor Productivity (TFP, henceforth) growth in European countries in the second half of the 20th century.

The study of the determinants of agricultural TFP is relatively widespread in the agricultural economics literature (Ball 1985, Kawagoe and Hayami 1985, Ball et al. 2001, Coelli and Rao 2003, Lerman et al. 2003, Headey et al. 2010), and some few economic historians have also made important contributions (Van Zanden 1991, Federico 2005 and 2011), although this kind of analysis is still not common.

The role of public institutions in agriculture has grown considerably in Europe since the Second World War (public intervention in the agricultural sector was virtually absent before the war) (Pinilla 2009). On the one hand, market-economy governments in the European Economic Community have intervened via the Common Agricultural Policy, or with similar policies for non-EU members, to protect their agricultural sector (Anderson and Valenzuela 2008, Josling 2009). On the other hand, central and eastern European countries have maintained strong controls over the economy (and a quasi-total public ownership of the means of production) during four decades of communist policy. Since the collapse of the Soviet hegemony, some of those countries have joined the EU, while others have maintained some level of intervention in the agricultural sector (Anderson and

Swinnen, 2008 and 2009). Our analysis attempts to clarify the influences of such institutional frameworks on the growth of agricultural productivity.

Another interesting question is, what is the real effect of geography on European agricultural productivity? The European continent presents a range of geographical contexts in which to observe the effects of climate (temperature and rainfall), orography, and annual hours of sunshine, among others, on agricultural productivity. The aridity of the Mediterranean countries and the cold temperatures of the Nordic countries obviously have an impact on agricultural productivity, but it is equally clear that technology makes it possible to overcome such geographical obstacles.

Our results provide some clear answers to these questions and allow a better understanding of the factors driving economic growth and, more specifically, the growth in agricultural productivity. Political rights, civil liberties, public support for agriculture, and an open economy all appear to be key variables in understanding growth. An extreme climate, such as a polar bioclimatic zone, tends to have a lower growth of productivity. On the other hand, the Mediterranean climate enjoys greater agricultural productivity, due, in part, to strong public support for increasing the extent of irrigated land. Also, we find a positive and significant relationship between human capital and agricultural productivity.

3.2. Methodology: Measurement of the agricultural total factor productivity

In this section, we present the methodology used to calculate agricultural TFP, as well as our main results.

The measurement of agricultural productivity can be partial or total, with the difference being the input and inputs that are taken into account. In our case, we calculate the Total Factor Productivity (TFP), "which is a productivity measures involving all factors of production" (Coelli et al. 2005, 3). This approach to productivity offers an overview of the efficiency of the sector. We compare change in output with changes in all inputs, and we follow the methodology of growth

accounting, implementing calculations following the work of Fuglie (2008, 2010 and 2012) and Wang et al. (2013, 242). TFP growth is represented as the ratio between the respective growth rates of output and a combination of inputs, where Y is the output and X is this combination:

$$\frac{d \ln (TFP)}{dt} = \frac{d \ln (Y)}{dt} - \frac{dln(X)}{dt}$$

As Fuglie (2012) pointed out, if producers maximize profits and the market for agricultural products is a long-run competitive equilibrium, then the previous equation could be written as:

$$\ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right) = \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \sum_i\left(s_{i,j,t}\right) \cdot \ln\left(\frac{x_{i,j,t}}{x_{i,j,t-1}}\right), \text{ i=1,...,N; j=1,...,5; t=1,...,T}$$

in which *Y* is the agricultural gross output, *X* is the vector incorporating the j-input, and *S* are the cost shares to combine the different inputs.

The output data have been sourced from FAOSTAT (2009) and FAO (1948-2004) and is valued at international 1999-2001 prices in dollars[51]. We have applied Hodrik and Prescott (1997) filters to soften the series.

The vector X includes several inputs: labour, i.e. the active population in agriculture[52], land, which we have taken as arable land and permanent crops in hectares, adding the irrigated land hectares multiplied by 2.145[53], machinery, i.e. agricultural tractors and associated equipment[54], and livestock, a combination of various animals, using Hayami and Ruttan's (1985) weightings. All of these inputs have been sourced from FAOSTAT (2009) and FAO (1948-2004)[55]. We have also measured the consumption of chemical fertilizers, as the sum of nitrogenous,

[51] Fuglie (2010 and 2012) calculated the output as the sum of all the agricultural products, weighted by their revenue share. The way that we can combine the FAOSTAT's database and the data from the yearbook from FAO are explained in Martín-Retortillo and Pinilla (2015a).
[52] The correct way to measure labour is with hours worked. The lack of availability of data for the whole sample of this variable complicates its use.
[53] Fuglie (2010) used this conversion factor to aggregate the land in developed countries and to take irrigation into account, as a way of considering the quality of this input.
[54] The correlation between the number of tractors and the weighted, lineal combination of steam engines, and harvesters in Europe, between 1961 and 2006 is 0.9766.
[55] The omission of certain inputs, such as pesticides or threshing machines, is due to the lack of available data. Despite that, we have assumed that the omitted inputs growth is the same as that of the group of inputs to which they belong. For more details about the calculation of these variables, see Martín-Retortillo and Pinilla (2015a).

phosphate and potash fertilizers and these data are from FAO (1948-2009) and from IFA (2014)[56].

Our methodology is sensitive to the choice of the applied weights for these various inputs. The difficulty in obtaining some of these weights, for each country and for each time period, has encouraged us to look for an alternative solution, and we have followed the cost share data presented by Fuglie (2012), as shown in Table 3.A.1. We have interpolated this data to calculate annual TFP growth[57], employing four different cost shares, distributed among countries as follows. Northern European cost shares for Austria, Belgium-Luxembourg, Denmark, Finland, France, German Federal Republic, Germany (after reunification), Ireland, the Netherlands, Norway, Sweden, Switzerland; Southern European cost shares for Greece, Italy, Portugal and Spain; USSR cost shares for Albania, Bulgaria, Czechoslovakia (and after its dissolution), German Democratic Republic, Hungary, Poland, Romania and Yugoslavia (and after its dissolution). The United Kingdom has its own cost share.

3.3. Evolution of Agricultural productivity

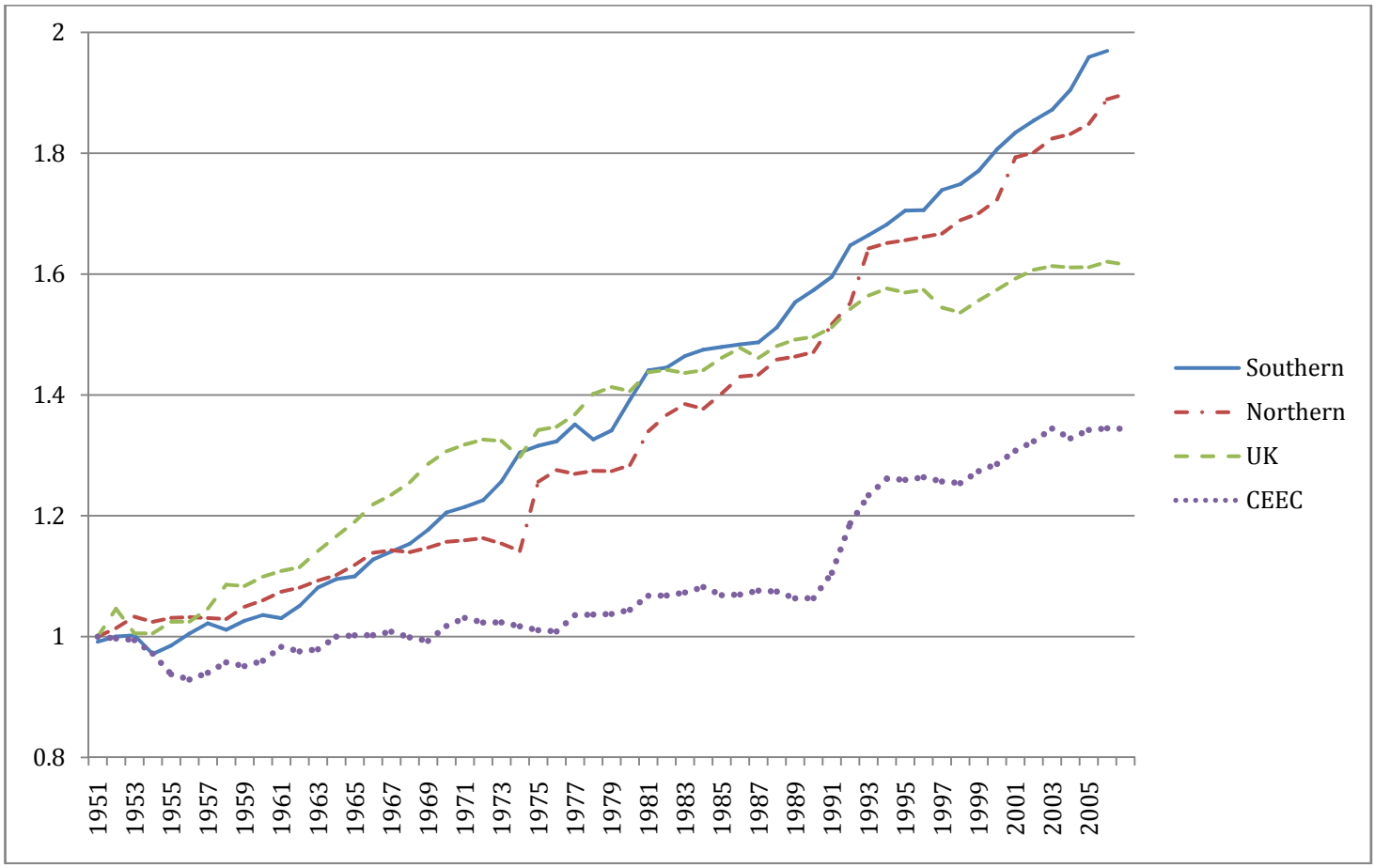
Graph 3.1 and Table 3.1 show the obtained results for agricultural TFP between 1950 and 2006. We have also performed our estimation for two sub-periods, with 1985 being the dividing point[58]. Our TFP estimations appear in four groups: the UK, Northern European countries, Southern European countries, and Central and Eastern European countries (CEEC, henceforth). We have estimated the European TFP with the average cost shares, weighted by agricultural production, and not weighted, to facilitate comparison.

These results provide several conclusions. The first is the acceleration of TFP growth throughout the period. In all countries, the rate is higher in the second sub-period, 1985-2006, than in the first. One explanation for this is the decrease or stagnation of several inputs in the production process, mainly agricultural labour, chemical fertilizers, and the stagnation of the numbers of agricultural machinery.

[56] The data from IFA (2014) begins in 1961. We have supposed that in the 1950s the evolution of chemical fertilizers is the same as that followed by FAO (1948-2004).
[57] Before 1961, we have assumed that the cost shares are equal to this year.
[58] Agricultural production in Europe has been stagnant since 1985. From 1950 to 1985, it grew strongly (Martín-Retortillo and Pinilla, 2015b).

(Note that TFP growth can still occur with stagnation of the output in the European countries, with fewer inputs employed.

Graph 3. 1. Accumulated agricultural TFP growth in the four European groups of countries.



Source: the same as Table 1.

Another explanation of this higher growth is the increasing importance of certain omitted inputs, such as biotechnology, and the new ICTs adopted by the sector. TFP collects the effect of these inputs, and the growing trend of this productivity could reflect this omission if their use grew faster than the other capital inputs. The development of high-yielding crops in extreme geographical conditions, for example, has had a significant impact in the sector[59] (Gardner 1996).

[59] Some examples of this biotechnology are high-protein triticales for animal-feeding in Europe, double-zero rapeseed growing in northern climates, nitrogen-fixing genes in non-leguminous crops and high-protein/high lysine content in winter wheat (Gardner 1996).

Table 3. 1. TFP growth (average logarithmic growth rates)

	1950-2006	1950-85	1985-2006
UK	1.10	1.37	0.70
Austria	1.75	1.18	2.64
Belgium-Lux	2.04	1.90	2.20
Denmark	1.92	0.84	3.74
Finland	1.23	1.19	1.33
France	1.71	1.21	2.53
GFR	-	2.20	-
Germany	-	-	2.75
Ireland	0.47	0.05	1.39
Netherlands	2.12	2.11	2.18
Norway	0.59	0.43	0.99
Sweden	1.09	0.67	1.95
Switzerland	0.67	0.14	1.50
Western	**1.60**	**1.23**	**2.25**
Greece	1.25	0.63	2.11
Italy	2.01	1.77	2.37
Portugal	0.98	-0.02	2.52
Spain	1.98	1.63	2.45
Southern	**1.73**	**1.37**	**2.25**
Albania	1.33	0.24	2.52
Bulgaria	1.79	1.69	1.92
Czecholosvakia	0.66	0.48	0.99
GDR	-	0.69	-
Hungary	0.77	0.46	1.45
Poland	0.09	-0.22	0.52
Romania	0.18	-1.18	2.23
Yugoslavia	1.37	1.03	1.99
CEEC	**0.61**	**0.20**	**1.25**
Europe (Not weighted)	**1.26**	**0.94**	**1.77**
Europe (Weighted)	**1.37**	**1.02**	**1.92**

GFR and GDR refer to the period 1950-1989. The German datum is for the 1991-2006. Data for Albania is only available since 1961, and the calculation of the Albanian TFP begins in that year. We have calculated the European aggregates through the average of the cost shares. We have weighted the European aggregate by agricultural production of the four groups of countries.
Source: For the cost shares, Fuglie (2012); Northern and Southern except UK (Ball et al. 2010; capital decomposition from Butzer et al. 2012), USSR (Lerman et al. 2003, 1965-1990; Cungu and Swinnen 2003, after 1992), UK (Thirtle et al. 2008). For the data, from FAO (1948-2004), FAOSTAT (2009) and IFA (2014).

A further conclusion is the existence of notable differences within the groups of countries. The Western European countries have shown remarkable growth, owing to the earlier adoption of certain technological advances, while structural change and the industrialization of the economy began sooner in this group. Although Southern countries were late in incorporating these changes, considerable growth occurred, especially in Italy and Spain. These countries had a strong agricultural sector and the incorporation of new technologies, once begun,

was greater than in Western countries. In other words, the Southern European countries tended to follow the Western technological pattern, but they soon increased their efficency and experienced a higher growth rate (Martín-Retortillo and Pinilla 2015b)[60].

The CEEC countries had a lower growth in agricultural productivity than the other groups, especially in the decades characterised by centrally-planned systems. This reflects the general lack of efficiency of the soviet-type economies, the agricultural sector being no exception. The large-scale incorporation of agricultural machinery and chemical fertilizers, and the lesser exit of workers led to a lower rate of growth in productivity. Despite large investments of capital, the new inputs from the industrial sector were poorly allocated and had little impact (Gray 1990). Our estimation of agricultural TFP is lower than that of Ofer (1987, 1778) for the period between 1950 and 1985, with lower efficiency in the agricultural sector than in the economy as a whole.

The differences within groups are less clear than among them. In the Western countries, for example, the most productive are those that were at the centre of the industrial revolution in Europe and developed sooner. The more productive countries had earlier structural change and a more timely incorporation of new technologies, especially in the first half of the 20th century (Grigg 1992, Federico 2005).

The Mediterranean countries follow two different trajectories. Italy and Spain had high TFP growth, almost at the same pace as the Western countries, while Greece and Portugal display low productivity growth.

In the Central and Eastern European countries, good results in Bulgaria, Yugoslavia, and Hungary contrast with poor results, in terms of TFP growth, in Czechoslovakia and Poland. Berend and Ranki (1985) and Lampe (1986) point to greater specialization and faster structural change as leading to the better productivity of countries such as Bulgaria and Hungary. Wong and Ruttan (1990) and Macours and Swinnen (2000 and 2002) show significant differences in productivity among these countries before and after the collapse of the central planning system. These authors establish that the primary determinants of the

[60] The possible differences between the Martín-Retortillo and Pinilla (2015b)'s results and Table 1's are due to the fact that in the first ones the calculation of TFP was made without taking into account the intermediate years between 1950, 1985 and 2005.

differences are in the initial conditions and in the reform policies during the transition (Macours and Swinnen 2002).

3.4. Determinants of agricultural productivity

We now specify two econometric models in which the dependent variable is the growth of TFP, and the explanatory variables are an approach to the underlying causes of economic growth, particularly the influence of geography and institutions.

Geographical factors - orography, temperature, rainfall, annual hours of sunshine, soil quality, plagues, pestilence, disease, and altitude – all play a fundamental role in explaining agricultural production and productivity (Grigg 1982 and 1992, Crosby 1986, Federico 2005, Asenso-Okyere et al. 2011). We approach the geographical influence through the percentage that each country has in each bioclimatic area or biome. (A bioclimatic zone consists of a number of variables, such as temperature, rainfall, orography, and annual hours of sunshine.) We use the data offered by CIESIN (2007) and we divide the continent into three zones: Western, Mediterranean, and Polar bioclimatic areas, with the Western area being the reference category.

The institutions are another fundamental factor of modern economic growth, although their influence is sometimes difficult to measure (Bardhan 1991). The degree of openness, the distribution of land property, the political support for the agricultural sector, the membership of regional trade agreements or economic unions, the extent of civil liberties and political rights, and the overall functioning of the economic system, all influence agricultural productivity (Fan and Zhang 2004, Helfand and Levine 2004, Vollrath 2007, Bharati and Fulginiti 2007, Lio and Liu 2009, Fan and Brzeska 2010, Ali et al. 2012).

We measure this institutional influence through several variables. The first two are *Civil liberties* and *Political rights* (Freedom House, 2014), measured on a 7-point scale, with 1 being the highest degree of freedom and 7 the lowest. We also include two variables related to economic policy: *Openness* and *Subsidies*. The first is a qualitative variable that takes the value 1 when the country is open and 0

when it is closed (Sachs and Warner, 1995)[61]. The second qualitative variable takes the value 1 if economic policy supports agriculture and 0 if the sector is not supported (Anderson and Valenzuela, 2008)[62]. However, it is necessary to be very cautious interpreting these two variables because of the strong assumptions made in their calculation.

Human capital also has a significant role in explaining differences in agricultural productivity[63]. Some studies have found a positive relationship, in that higher education encourages greater knowledge, the use of more innovative techniques, and the more appropriate crop for each farm (Nguyen 1979, Kawagoe et al. 1985, Hayami and Ruttan 1985, Gardner 2002). We measure human capital in two ways: first, through the Gross Enrolment Ratio (GER) for secondary school, obtaining the data from World Development Indicators (2011) and Mitchell (2007), and, second, through the total years of schooling with data from Barro-Lee's database (World Development Indicators 2011) and Mitchell (2007) [64].

To ascertain the importance of the main determinants of European agricultural productivity, we first carry out a cross-country estimation (Table 3.3), following Headey et al. (2010), in which the explanatory variable is average agricultural TFP growth between 1950 and 2006[65].

The results show the importance of geography, institutions, and human capital in the growth of agricultural TFP (Table 3.2). In terms of geography, the polar climate, assumed to be an obstacle to Nordic productivity growth, has negative sign and is significant. The Mediterranean climate, despite its aridity, is significant and shows a positive sign as a result of the regional reliance on

[61] We have followed the classification of Sachs and Warner (1995). The main problem is the omission of certain countries in that paper. For the countries for which those authors have no data, we use the World Development Indicators and Maddison data. In cases where neither database allowed us to make a decision, we have supposed that an EU member was an open country.
[62] All the assumptions of this variable are in Martín-Retortillo and Pinilla (2015a).
[63] The estimated TFP also includes improvement in human capital. Thus, it is essential to include this in our econometric model.
[64] All the assumptions of this calculation for GER secondary are from Martín-Retortillo and Pinilla (2015a). The assumptions for the calculation of Schooling are the same as for GER secondary.
[65] Headey et al. (2010) explain the average TFP growth. These authors dismiss other objective variables such as the evolution of TFP growth, owing to the volatile and often cyclical nature of agricultural output (Headey et al. 2010, 8).

irrigation (Cazcarro et al. 2015); the combination of abundant annual sunshine with this irrigation produces rapid agricultural productivity growth[66].

Table 3. 2. Results. Dependent growth variable: Average TFP growth, 1950-2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation	MCO robust	MCO robust	MCO robust	MCO robust	MCO robust	MCO robust	MCO robust
Mediterranean	.8368***	.7513***	.4840	.3958	.2613	.4863*	.5158*
	.2782	.2647	.2951	.2815	.3038	.2579	.3005
Polar	-.8929**	-.8348**	-.7129**	-.6563**	-.6712*	-.6308*	-.2849
	.3562	.3456	.3271	.3134	.3702	.3339	.3509
GER	.0203***	.0195***	-	-	.0095	.0154***	-
	.0025	.0023			.0027	.0028	
Schooling	-	-	.0055	.0022	-	-	.1340
			.0619	.0637			.0326
Civil Liberties	-.1254**	-	-.1567**	-	-	-	-
	.0597		.0585				
Political Rights	-	-.1052**	-	-.1344**	-	-	-
		.0542		.0515			
Openness	-	-	-	-	1.0021**	-	-
					.3636		
Subsidies	-	-	-	-	-.2320	-	-
					.3121		
EU	-	-	-	-	-	.5560	.8136**
						.3554	.3581
Communist	-	-	-	-	-	-.4051	-.2367
						.3865	.3722
Constant	-	-	1.7501***	1.6981***	-	-	-
			.4494	.4570			
Countries No.	32	32	32	32	32	32	32
R^2	0.8635	0.8611	0.2092	0.2003	0.8713	0.8785	0.8487

The data below the coefficients are the standard deviations. The coefficients *, ** and *** are significant at 10, 5 and 1% respectively.

The model also highlights the importance of institutions in productivity growth. On the one hand, the two variables measuring political rights and civil liberties have negative sign and are significant. That is to say, a society with greater civil liberties and more political rights encourages a higher agricultural productivity. A country with more such freedoms encourages agricultural TFP, providing farmers, groups, and organizations with a greater power of choice in changing the production process (Gallego 2007). There are several examples of the importance of power of choice in agriculture, such as the inputs used, the different products produced, the distribution channel selected, the modes of interaction, and

[66] Despite the higher growth in agricultural productivity, there are several environmental problems caused by application of this intensive production process (Cazcarro et al. 2015).

the possibility of voicing disagreement with agricultural policy decisions. Farm efficiency would be reduced without the farmer's power of choice, and the lack of power of choice in centrally-planned systems goes some way to explain the average agricultural TFP under those systems.

The main differences in civil liberties and political rights in European countries are between the communist countries and the market economies. The centrally-planned economies experienced less structural change than the market economies because of the maintenance by government of the workforce in the agricultural sector (Gregory and Stuart 2001). In the case of labour, the planned economies had serious problems of incentives (Federico 2005). While the large-scale incorporation of technical inputs by the state, primarily machinery and chemical fertilizers, proceeded at more or less the same pace as in the Western countries and the USA, the rate of increase in capital intensity and the allocation of these investments was greater in the market economies (Gray 1990, Harrison 1996). This incorporation was not the same for all state, collective, and private farms, since the government did not take into account the needs of the farms, which reduced the productivity gains that these innovations could contribute to the production process (Landau and Tomaszewski 1985). Specialization in the agricultural sectors in these countries was rare, leading to a loss of productive potential (Gregory and Stuart 2001, Federico 2005), and this affected negatively agricultural productivity, because of less efficient maintenance of farm resources.

The more open economies show greater average TFP growth, due to three positive influences: access to larger markets for agricultural products, ease of buying inputs, especially from the non-agricultural sector, and greater international competition that encouraged the most competitive farmers. The countries of the European Union have these advantages, along with commercial protection in terms of non-EU competition, which provides farmers with a certain level of economic security (Ritson 1997, Andreosso O'Callaghan 2003). However, the *subsidies* variable is not significant.

Human capital has an important role in explaining the determinants of agricultural productivity growth. In the case of measurement of the Gross Enrolment Ratio in secondary education, this variable is always significant and has

a positive sign; that is to say, the higher the gross enrolment ratio, the greater the growth in agricultural TFP. The other measurement of human capital, years of schooling, is not significant.

We have carried out a second analysis using panel data, taking the annual TFP growth series for each country as the explanatory variable. We have used the Hodrick-Prescott filter for agricultural production, a test that reduces the oscillations in agricultural output. We also estimate the determinants of TFP growth with a greater number of observations than before, but correcting the problems "of the volatile and often cyclical nature of agricultural output" (Headey et al., 2010: 8)[67]. The results of this second analysis are shown in Table 3.3.

We include in these estimations two qualitative variables: EU and Communist, measuring EU and non-EU membership, with 1 for members, and 0 otherwise.

We reject the null hypothesis of homoskedasticity and not autocorrelation, using the Wald (Greene 1997) and Wooldridge tests (Wooldridge 2002), respectively. To solve these problems, we estimate with robust standard deviations in the OLS, RE data, and Panel Corrected Standard Errors (PCSE).

We have estimated the models in columns 1, 3, 4, 5, 6, and 8, with robust OLS pooled data, following the methodology of Heady et al. (2010). In all cases, we have used the Breusch-Pagan LM test and the F-test (Greene 1997) to test whether the estimations of panel data are preferable, comparing with OLS pooled data. We have rejected at 5% of significance the null hypothesis of OLS pooled data, in all cases, with the exceptions of columns 3, 4 and 5, which are final estimations. We have run various models to reinforce our initial estimations of this table (columns 1 to 3), as well as the results of Table 3.2.

The first five estimations in Table 3.3 are similar to those in Table 3.2, but with panel data. The estimations in columns 1 and 3 are OLS robust estimations,

[67] When we replicate the estimations with five- and ten-year growth rates, the main results do not change.

without the constant because it is not significant[68]. The estimation in column 2 is Random Effects with robust standard deviations for the coefficients, because we have not rejected the null hypothesis of Random Effects with the Hausman test.

Table 3. 3. Results. Dependent variable: Annual TFP growth, 1950-2006

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimation	MCO robust	RE robust	MCO robust	MCO robust	MCO robust	RE robust	RE robust	RE	PCSE
Mediterranean	.589*	.584**	.478	.400	.263	.627**	.499*	.436	-
	.347	.268	.333	.402	.379	.281	.280	.347	
Polar	-.831*	-.838**	-.789*	-.441	-.394	-.757**	-.700**	-.669*	-
	.457	.373	.458	.568	.567	.372	.364	.363	
GER secondary	.019***	.018***	.019***	.015***	.015***	-	-	-	-
	.003	.004	.003	.004	.004				
Ln (GER secondary)	-	-	-	-	-	1.084***	1.121***	-	-
						.233	.236		
Schooling	-	-	-	-	-	-	-	.140***	.170*
								.048	.089
Civil Liberties	-.173***	-.261***	-	-.242**	-	-.251***	-	-.222***	-.231**
	.047	.082		.118		.082		.085	.098
Political Rights	-	-	-.160***	-	-.196	-	-.219**	-	-
			.045		.135		.089		
Openness	.773***	.608*	.751**	.528	.561	.608**	.600*	.793**	.302
	.288	.322	.290	.424	.427	.304	.327	.314	.362
Subsidies	-.617**	-.868***	-.626**	-1.188***	-1.115***	-.853***	-.825***	-.747**	-.699**
	.262	.281	.267	.370	.378	.272	.314	.324	.367
EU	-	-	-	.681**	.672**	-	-	-	-
				.328	.332				
Communist	-	-	-	-.056	-.055	-	-	-	-
				.690	.814				
Constant	-	.674	-	.862	.640	-2.612**	-2.890***	.717	.001
		.610		.556	.546	1.100	1.098	.612	.079
No. Observations	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381
R^2	0.168	0.326	0.167	0.059	0.057	0.292	0.280	0.217	0.012

The data below the coefficients are the standard deviations. The coefficients *, ** and *** are significant at 10, 5 and 1% respectively.

These first three estimations (columns 1 to 3) show the same conclusions as those in Table 3.3. As we have seen, the Mediterranean climate encourages greater

[68] We have estimated without constant only in the cases of OLS robust estimations when the constant is not significant.

TFP growth and the Polar climate is detrimental to it. Additionally, greater civil liberties and political rights benefit increased growth of total productivity. In the panel data estimations, *openness* is not significant in the robust random effects estimation. The variable *subsidies* has negative sign and is significant. This last variable could be negative because strong political support for agriculture could encourage maintaining inputs in the sector, such as labour, land, and capital, which would minimize TFP growth. If this policy did not exist, the maintenance of these inputs would be difficult, probably because of migration to non-agricultural activities.

The existence of strong policies in support of agriculture, as in the Common Agricultural Policy (CAP henceforth), encourages maintaining workers, and other resources in the agricultural sector, reducing growth in agricultural TFP. Although this policy promotes increasing agricultural production, the maintenance of certain resources diminishes productivity growth. Features of the CAP, such as export subsidies and minimum prices (Tracy 1989; Ritson 1997; Andreosso-O'Callaghan 2003; García Delgado and García Grande 2005, Neal 2007), encourage farmers to remain in the sector. In the case of CEEC countries, increases in agricultural support brought with it inefficiencies and cost increases (Gray 1990).

In estimations 4 and 5 we have included dummies for membership of the communist and European Union groups of countries. Membership of the communist group is not significant, but EU membership is, with the EU being strongly related to *openness*, because of open markets, improved access to technical inputs and investments, and the protection of the CAP in relation to the rest of the world.

Testing the robustness of our estimations, the next four models include a different measurement of human capital. In columns 6 and 7, the human capital is the Gross Enrolment Ratio in logarithms. The main results do not change and the principal difference is interpretation, with the double-logarithm estimations showing elasticity, and the previous estimations showing semi-elasticity.

Finally, we change the variable of human capital in the last two estimations (columns 8 and 9), replacing the previous measurement by the years of schooling.

We have applied the same chain tests, testing the preference among Random, Fixed, and OLS estimations. In this case, we reject the Hausman test null hypothesis of Random Effects, and we estimate with PCSE[69]. When we estimate with years of schooling as a measure of human capital, the main change is the non-significance of the openness variable.

3.4. Conclusions

Agricultural productivity has been the subject of many analyses in the agricultural economics and economic history literature, and the determinants of the variable have been a special focus, but analysis of the underlying causes of productivity growth is much less common in the European context. In this work, we concentrate on Europe in the second half of the 20th century, a period of strong growth in agricultural productivity.

We have calculated TFP growth in the agricultural sector since the Second World War, and estimated two econometric models to analyse the main determinants of this variable: the first is a cross-country analysis, with average TFP growth between 1950 and 2006 being the explanatory variable, and the second is a panel data analysis with annual agricultural TFP growth as the dependent variable.

Both models, show that the fundamental causes have a remarkable role in explaining the differences in agricultural TFP growth. It turns out that institutions significantly affect our target variable, and the existence of civil liberties and property rights in society encourage greater agricultural productivity. Furthermore, a more open economy leads to increases in agricultural productivity, while strong political support for the agricultural sector allows resources to be maintained that actually reduce productivity growth.

Geography is also a major influence on agricultural productivity. Having more land in a polar bioclimatic zone discourages agricultural TFP growth because of the extreme temperatures during much of the year, while the Mediterranean

[69] The variables in the PCSE estimation are transformed into deviations according to their individual, temporal, and overall average.

climate has a positive influence on agricultural productivity, especially when paired with irrigation infrastructure.

Appendix

Table 3.A. 1. Cost Shares employed to obtain agricultural TFP

NorthWestern Europe except UK	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Labor	0.334	0.334	0.244	0.235	0.22
Land	0.04	0.04	0.074	0.079	0.069
Livestock	0.261	0.02	0.024	0.017	0.013
Machinery	0.073	0.073	0.104	0.134	0.134
Chemicals	0.292	0.533	0.554	0.535	0.564
Southern Europe	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Labor	0.577	0.577	0.45	0.404	0.469
Land	0.085	0.085	0.124	0.154	0.096
Livestock	0.016	0.016	0.018	0.014	0.01
Machinery	0.059	0.059	0.076	0.114	0.105
Chemicals	0.263	0.263	0.331	0.313	0.319
CEEC	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Labor	0.104	0.104	0.104	0.19	0.19
Land	0.257	0.257	0.257	0.23	0.23
Livestock	0.453	0.453	0.453	0.42	0.42
Machinery	0.043	0.043	0.043	0.09	0.09
Chemicals	0.143	0.143	0.143	0.07	0.07
UK	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Labor	0.327	0.164	0.136	0.137	0.137
Land	0.084	0.126	0.179	0.216	0.216
Livestock	0.251	0.333	0.284	0.235	0.235
Machinery	0.183	0.199	0.202	0.204	0.204
Chemicals	0.155	0.178	0.199	0.209	0.209

Source: Fuglie (2012); Northern and Southern except UK (Ball et al. 2010; capital decomposition from Butzer et al. 2012), USSR (Lerman et al. 2003, 1965-1990; Cungu and Swinnen 2003, after 1992), UK (Thirtle et al. 2008).

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Chapter 4. The dynamics of agricultural production growth in the second half of the twentieth century: is there a Latin American pattern?

4.1. Introduction

The profound worldwide transformations in the agricultural sector in the second half of the twentieth century have generated an enormous academic interest. Diverse scientific perspectives have been employed to analyse some of their most notable aspects, such as technological change, including the significance and consequences of the Green Revolution, the increase in production, the changes in social relationships, the evolution of the distribution of property and the attempts at agricultural reform or, in general, the evolution of rural societies.

The sharp increase in agricultural production, its causes and the great regional variations which have existed in these processes of growth have been one of the themes which, from an economic perspective, have gathered greatest attention. As is well known, following the Second World War agricultural production grew more quickly than the world population, thereby generating simultaneously situations of excess supply in some world zones and of food insufficiency or even hunger in others (Federico, 2005). This growth of production is explained in large part by technical change, which while very deep-rooted, has been very unequal from a geographical point of view. The Green Revolution, initiated in the 1940s in Mexico and transported from there later to many other zones of the world, has played an important role in the increase of production.

The enormous regional variation in the patterns of growth of agricultural production has generated notable interest and in recent years a considerable number of studies have attempted to establish a certain taxonomy of these experiences of agricultural growth.

Given this context, the object of the present study is to attempt to analyse the case of Latin America. Firstly, we are interested in analysing its pattern of growth in comparison to that of other world regions, trying to discover if it is possible to speak of a Latin American pattern differentiated from that of other continents and regions. Secondly, we wish to determine if there exists a single Latin American pattern or whether in fact the enormous differences within this region require us to speak of various paths of agricultural growth.

Due to the difficulty of not having data available for all the variables necessary for the complete period of 1950-2008, we have had to dispense with some countries, normally medium-sized or small. However, the countries included

in our study (Argentina, Brazil, Chile, Colombia, Honduras, Mexico, Panama, Peru, Uruguay and Venezuela) represent a huge majority of agriculture in Latin America, given that between 1965 and 2005 they accounted for between 85 and 90 per cent of its gross agricultural production.

We believe that very few studies have analysed the evolution of agriculture in Latin America as a whole from the perspective which interests us, although there are many more of a national character. Especially for the extended time horizon we propose, such studies are few. In general, other topics have stimulated greater interest, such as the changes in agricultural ownership, the attempts at agricultural reform or the development policies followed and their effects on agricultural sectors.

To achieve the objectives proposed we have had to previously construct a quantitative database upon which to found our analyses. It originates largely from the FAO statistics, although especially for the 1950s it has been necessary to perform a series of estimations (see Appendix). We have used this database to calculate the evolution of agricultural production and that of the inputs employed. Thus, it has been possible to calculate the partial productivities of labour and land and total factor productivity, and thereby determine to what extent increases in production are explained by the use of more factors or by an improvement in efficiency.

4.2. Latin America and the patterns of growth of agricultural production in the second half of the twentieth century

In the second half of the twentieth century world agriculture underwent profound transformations. Some of these came from better techniques, such as the massive use of chemical fertilisers, self-propelled agricultural machinery or the genetic selection and hybridisation of seeds. Latin America was not removed from them. But not only were there changes in the technology employed, but modifications to the agricultural policies implemented by each country also took place, and similarly to their trade and regional integration policies, which created different systems of incentives to agricultural activity. The distinct adoption of these transformations, both technical and institutional, meant important differences in the agricultural development of the various countries.

Table 4. 1. World Agricultural Production and Productivities, 1965-2005

Agricultural Production (Y)	1965	1970	1975	1980	1985	1990	1995	2000	2005	Annual Growth Rate (%)
Eastern Europe										0.53
Western Europe										0.98
North America										1.72
Latin America										3.02
AUS+NZL										1.68
Southern Asia (Central and East)										3.10
China, mainland										4.41
Japan										0.61
Middle East and North Africa										3.13
Sub-Saharan Africa										2.71
Labour productivity (Y/L)										
Eastern Europe	1,664	1,870	2,312	3,135	3,694	4,059	4,191	5,004	6,365	3.41
Western Europe	5,347	7,719	10,001	11,905	14,510	17,258	20,593	25,411	29,034	4.32
North America	19,974	31,122	42,842	33,119	36,372	40,202	50,709	59,474	70,666	3.21
Latin America	1,993	2,333	2,562	2,735	3,042	3,433	3,909	4,586	5,572	2.60
AUS+NZL	28,794	33,161	38,048	36,875	38,110	38,556	44,393	54,082	51,339	1.46
Southern Asia (Central and East)	447	489	522	556	614	664	731	786	853	1.63
China, mainland	316	315	360	312	376	416	540	677	819	2.41
Japan	1,051	1,531	2,038	3,082	3,749	4,333	5,344	6,696	8,872	5.48
Middle East and North Africa	1,103	1,284	1,457	1,741	1,929	2,148	2,513	2,817	3,308	2.78
Sub-Saharan Africa	537	620	621	604	597	650	663	694	757	0.86
Land productivity (Y/A)										
Eastern Europe	760	845	996	1,073	1,157	1,141	969	997	1,126	0.99
Western Europe	1,363	1,550	1,752	1,952	2,079	2,129	2,195	2,335	2,344	1.36
North America	487	499	577	650	678	707	810	903	1,009	1.84
Latin America	675	697	743	847	932	994	1,070	1,248	1,359	1.77
AUS+NZL	416	415	443	464	469	488	667	681	647	1.11
Southern Asia (Central and East)	419	483	534	619	732	838	984	1,097	1,232	2.73
China, mainland	705	821	968	1,175	1,285	1,529	2,075	2,623	3,295	3.93
Japan	2,306	2,772	3,114	3,472	3,778	3,813	3,832	3,760	3,761	1.23
Middle East and North Africa	392	450	514	599	705	805	912	1,078	1,232	2.90
Sub-Saharan Africa	294	334	368	404	417	477	504	568	642	1.97
Land-Labour ratio (A/L)										
Eastern Europe	2.19	2.21	2.32	2.92	3.19	3.56	4.32	5.02	5.65	2.40
Western Europe	3.92	4.98	5.71	6.10	6.98	8.11	9.38	10.88	12.38	2.92
North America	40.97	62.39	74.26	50.96	53.63	56.85	62.64	65.88	70.03	1.35
Latin America	2.95	3.35	3.45	3.23	3.26	3.45	3.65	3.68	4.10	0.82
AUS+NZL	69.21	79.97	85.84	79.52	81.23	79.09	66.55	79.40	79.35	0.34
Southern Asia (Central and East)	1.07	1.01	0.98	0.90	0.84	0.79	0.74	0.72	0.69	-1.07
China, mainland	0.45	0.38	0.37	0.27	0.29	0.27	0.26	0.26	0.25	-1.46

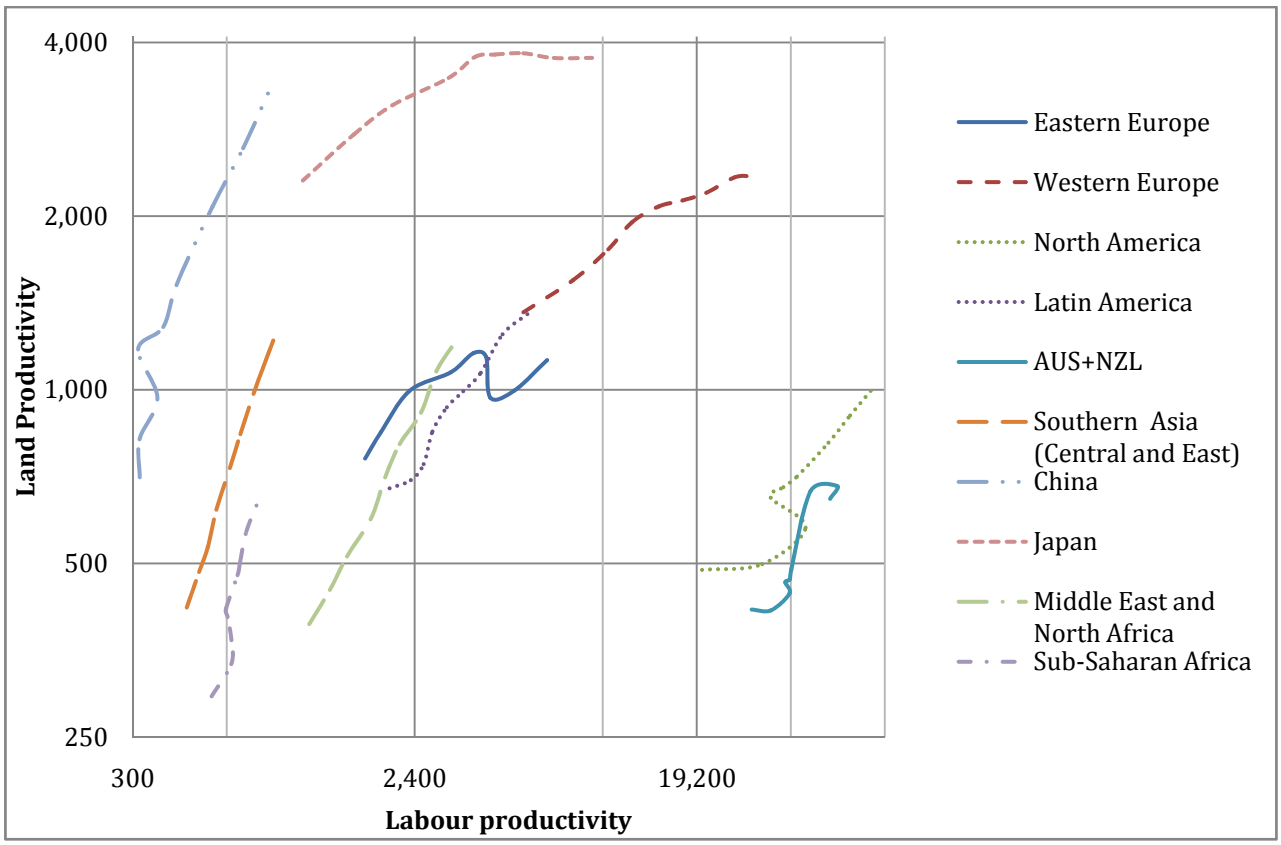
Japan	0.46	0.55	0.65	0.89	0.99	1.14	1.39	1.78	2.36	4.19
Middle East and North Africa	2.81	2.85	2.83	2.90	2.74	2.67	2.75	2.61	2.69	-0.11
Sub-Saharan Africa	1.82	1.86	1.69	1.49	1.43	1.36	1.31	1.22	1.18	-1.08

Source: FAO (1948-2004) and FAOSTAT (2014)

If we examine in first place the variation in agricultural production, we can observe that its growth was far greater in the developing regions than in the developed countries (Table 4.1). Thus, in the former their increase in absolute terms normally exceeded 200% between 1965 and 2005, while in the developed countries this was no greater than 100%, and normally less. In this context, the growth of Latin America fits perfectly with the model of developing countries.

How were these increases in production achieved? Worldwide data show clearly that there were highly varied increases in the inputs employed in some regions (there were even decreases, as in Europe with labour), but in all the regions of the world there were sharp increases in productivity, whether from labour or the land or, most commonly, simultaneously from both. Graph 4. 1 shows the diversity of experiences, if we take into account the starting levels and the increase in productivity of land and labour. It can be said, in general terms, that in the developed countries there was a great increase in labour productivity, due both to increases in the productivity of the land and in the land-labour ratio. By contrast, in developing countries, the growth of labour productivity was considerably lower and was based on increases in the productivity of land normally greater than those of the developed countries, while the land-labour ratio worsened. Thus, there are two very different models of agricultural development: firstly, that of the developed countries, which had a moderate increase of production and strong gains in productivity due to both biological improvements and a strong increase in mechanisation, and to decreases in the absolute numbers of the agricultural labour force; secondly, in developing countries, production grew much more, although labour productivity did so less, its growth basing itself on a sharp increase in the productivity of land, while mechanisation played a minor role due to the strong demographic pressure these countries underwent, which meant increases in the absolute number of agricultural workers in all of them (although their percentage with regard to the total active population decreased).

Graph 4. 1. Land and labour productivities (world regions)



Source: The same as in Table 4.1

Where can Latin America be placed between these two models? It can be said that it is a peculiar case, since it shares characteristics with both and appears to be located in an intermediate situation, starting from that typical of developing countries it appears to converge towards that of the developed countries. Its growth of production is similar to that of the developing countries, but its growth of labour productivity has been based as much on an increase in land productivity as in the land-labour ratio. In fact, it is the only region of the developing world in which in recent years the number of agricultural manpower has already begun to decrease.

Such an aggregate analysis explains little, however. Latin America is very diverse from the geographical, climatic, social or institutional point of view. As Solbrig (2006, p. 535) stated, within Latin America "diversity was and continues to be a characteristic of the agriculture of this vast region, a result of the variety of climates, topography, history, and societies". We believe, consequently, that a serious understanding of the dynamics of the growth of agricultural production requires consideration of the experiences of the diverse countries, to attempt to

determine to what extent there exists a sole Latin American pattern, or whether the aggregate result mentioned conceals highly diverse trajectories.

To this end, we wish to observe and explain the growth of agricultural production in Latin America –at an annual rate of 3% in the last 60 years- determining whether the process has been a response to increases in the use of productive factors, and which of these have been most important, or whether it has been due to efficiency gains and increases in the total factor productivity of the Latin American countries. To this end, it will be necessary to calculate the increase in the use of the inputs in the agricultural sector, as well as the gains in total factor productivity (TFP). Furthermore, we shall also study the evolution of the partial productivities of land and labour.

In order to have a complete vision of the second half of the twentieth century, our analysis is centred on the period 1950-2008. With the intention of identifying performance patterns of agriculture three periods are distinguished: the phase of implementation of the policies of import-substituting industrialisation (ISI) (1950-1973), a second period comprising the years of the oil crisis, the foreign debt payment crisis and the initiation of the economic stabilisation programmes (1973-1993) and, finally, the phase of structural reforms and reintegration into international trade (1993-2008)[70]. During the first period, in those republics which implemented ISI policies, the role and functions of the state grew, as did important changes in the modalities of regulation of productive activities (taxes, subsidy fees, tariffs). With regard to agriculture for export, it is possible to identify a bias against the sector; this attempts to be compensated for by subsidised credit and the purchase of fertilisers.[71] Consequently, export agriculture had negative protection rates, while the opposite was true for that aimed at the domestic market. In the second period the context of economic crisis, the exhaustion of ISI and the foreign debt crisis created the conditions for the

[70] To establish a criterion to divide the period as a whole, we have observed empirically in an econometric fashion when a structural change occurs in Latin American agricultural production as a whole. We performed the test proposed by Kejriwal and Perron (2010). This approach showed us that there was a structural break in 1993, in which the statistic was 22.15. To avoid establishing two subperiods so unequal in time we performed another break in 1973.

[71] Anderson and Valenzuela (2010) offer a discussion of the magnitude to which national policies have modified the incentives of agricultural prices, trade, economic wellbeing and poverty in the period 1965-2004. The countries considered are Argentina, Brazil, Chile, Colombia, the Dominican Republic, Ecuador, Mexico and Nicaragua.

change to a development model aimed at export growth. Finally, the third period was one of a deepening of adjustment policies and structural reforms, performed in the last years of the 1980s and the first of the 1990s. As a result of the redefinition of the role of the state and the implementation of policies aimed at favouring the free market, the economy as a whole, and agriculture in particular, underwent changes in their productive structure, competitiveness, productivity and profitability (David et al., 2001).

To achieve our objective we shall estimate the agricultural production of the distinct countries, as well as the use of productive factors (the land employed, animals, the use of chemical fertilisers, machinery and the land area equipped for irrigation). Calculating the difference of the growth in production with increases in the inputs, we can obtain the total factor productivity (TFP) in agriculture, applying the corresponding weightings to each input.

4.3. The evolution of production and use of productive factors

4.3.1 The expansion of agriculture with varying performance

Latin American agricultural production has experienced an unprecedented expansion since the 1950s, with an average annual growth rate of almost 3%, which means it multiplied five and a half times in 58 years (see Table 4.2). Especially notable are the cases of Brazil and Mexico, which grew at an average annual rate of 4% and 3.6% respectively, leading the expansion throughout the whole period, although with different characteristics. While Brazil became one of the world powers in the production of agricultural and livestock commodities at the start of the twenty-first century, Mexico underwent a sharp expansion during the 1950s and 1960s, to then slow down from the 1980s onwards. By contrast, the lowest increases in agricultural production took place in Argentina and Uruguay, with average annual growth of merely 1.3% and 1.6% respectively. These are agricultures specialized in production in temperate climates (livestock, cereals), which displayed a very significant dynamism at the last decades of the nineteenth century and the initial years of the twentieth century, which permitted them to reach very high levels in terms of production and the use of factors prior to the Second World War (WWII).

Table 4. 2. Agricultual Gross Production

	Mill. US $ 2004-2006 prices				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	12,186	14,277	19,487	30,370	0.7	1.6	3.0	1.6
Brazil	8,265	20,707	41,708	79,744	4.1	3.6	4.4	4.0
Chile	1,466	1,966	3,935	5,809	1.3	3.5	2.6	2.4
Colombia	2,980	5,260	9,290	12,931	2.5	2.9	2.2	2.6
Honduras	381	852	1,367	2,195	3.6	2.4	3.2	3.1
Mexico	4,461	14,188	23,912	35,271	5.2	2.6	2.6	3.6
Panama	232	493	784	1,293	3.3	2.3	3.4	3.0
Peru	1,312	2,129	2,783	6,301	2.1	1.3	5.6	2.7
Uruguay	1,211	1,313	1,686	2,521	0.4	1.3	2.7	1.3
Venezuela	1,557	4,155	7,381	10,960	4.4	2.9	2.7	3.4
Latin America	34,050	65,338	112,333	187,397	2.9	2.7	3.5	3.0

Data after 1961 from FAOSTAT (2012). For the previous decade, data from FAO (1948-2004). We have used the production indexes since 1948 to obtain a homogeneous serie for the whole period. Triennal averages, except 1950.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

In the subperiod coinciding with ISI (1950-1973), the average annual growth of Latin American agriculture was slightly below that of the period as a whole (2.9%). The countries which most increased their growth were Mexico,[72] Venezuela and Brazil, with rates of 5.2%, 4.4% and 4.1%, respectively. The three countries have in common an integrationist conception of ISI, in which agriculture should serve as a support for the process of industrialisation itself and nurture itself from it, and an active state, involved in technological development (linked to the Green Revolution[73]) and important institutional changes such as those related to agricultural reform.

In turn, the countries which had the slowest growth were, as in the period as a whole, Argentina and Uruguay, with weak rates under 1% annually (0.4% and 0.7% respectively). In both cases, the 1950s and 1960s were dominated by a policy

[72] For a discussion of the contribution of agriculture to the Mexican process of industrialisation, see Calva (1999).
[73] The transfer of technology from abroad was particularly important in the case of Mexico where, via the Rockefeller Foundation and an agreement with the Ministry of Agriculture, programmes of research and support for the improvement of the performance of various cereals were created (Brown, 1970) and the creation of research institutes was encouraged (Fernández-Cornejo & Shumway, 1997).

of industrial promotion which involved the transfer of resources from the agricultural sector to the manufacturing sector (with profuse rent-seeking activities), and similarly diverse restrictions on the importation of machinery and inputs, which meant severe negative effects for the production of agricultural commodities (Lence, 2010).

The growth of Latin American agricultural production between 1973 and 1990 was the lowest in the entire period, although very close to that of the previous stage (2.7%). In this subperiod, Brazil became once more the country with the highest annual growth rate of its agricultural production (3.6%), followed this time by Chile (3.4%) and Colombia (3.2%). In the case of Chile, the period coincides with the general takeoff of an economy based, as a political strategy, on the promotion of exports (above all those of a non-traditional character, such as fruit and flowers (Olavarría et al., 2004). In turn, Colombian agriculture had its golden age from WWII until 1980 (Kalmanovitz, 2005) and, as in the Chilean case, a large part of this success depended on the export vocation of production (where the traditional coffee was joined by palm oil).

As before, Uruguay and Argentina were the countries which least increased their production, with annual growth rates of 1.1% and 1.5%. Both economies presented, as in Chile, rapid and significant processes of economic liberalization (in a conception which was identified with the monetary approach of the balance of payments) with reduced tariffs on imports and fees on exports, but accompanied by rigid exchange rate policies which affected the competitiveness of agriculture without receiving in exchange special programmes of promotion or support. Peru also displayed meagre results during a period which included diverse agricultural policies such as price controls to guarantee the low cost of the food basket until 1979 (Álvarez, 1983) and a heterodox programme of the expansion of demand during the 1980s which resulted in a process of hyperinflation.

The greatest annual growth of Latin American agricultural production took place between 1990 and 2008 with an average rate of 3.3%, the leaders being Peru (4.7%) and Brazil (4.3%). In the former, it stands out that the execution of the stabilization programme and the structural reforms of the state modified the institutional framework and the conditions in which agricultural producers participated in market relations (von Hessen, 2000; Escobal, 1999). In particular,

the explicit policy of stimulating investment in the agricultural sector and the liberalisation of the market for food and agricultural inputs and of the land market were determining aspects. Meanwhile, Brazil consolidated an expansionary trajectory where, progressively, its extensive character of the preceding decades gave rise to a dynamic of increasing intensification in the use of factors (Mendali et al., 2013).

In turn, the lowest increases were produced in Colombia and Uruguay, with rates of 2% and 2.6%. Colombia displays a contrast with the previous period, since its agricultural sector entered into a phase of great difficulties dominated by real revaluations of the currency and sizeable capital movements (in a type of "Dutch disease").

The evidence of changes in leadership in the expansion –in which only Brazil remained in the leading positions throughout the period- is a reflection of Latin American heterogeneity. The dispersion of production levels increased significantly and its variation coefficient moved from a level of 1.15 in 1950 to one of 1.31 in 2008, demonstrating an increasingly disparate evolution among the continents' agriculture.

The composition of production, between crops and livestock, experienced moderate changes in the period. Crops had always represented, in Latin America as a whole, and in all its countries, except for Argentina and Uruguay, a majority of production. Until 1990 crop production was approximately 60% of total production, although from that date on its importance fell slightly, to 57%. In both Argentina and Uruguay the share of crops rose. In the former, the production of crops became predominant, rising from over 40% at the beginning of the 1960s to 62% of the total in 2008. In Uruguay the importance of crops rose, although not by the magnitude of Argentina (between the same dates it rose from 19.87% to 32.55%).

4.3.2. The use of inputs: the incorporation of land and labour and greater capitalisation

From the supply side, the growth of agricultural production may be due to a greater use of the inputs. Thus, we shall proceed to study the incorporation of land,

labour and capital into agricultural production. It is important to emphasise that it is only possible to measure those forms of capital for which there are data at an international scale and for a wide chronological horizon[74]. Despite this absence of quantitative data, we shall evaluate their importance when we discuss changes in agricultural productivity.

Table 4. 3. Arable land and permanent crops

	Thousands of hectares				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	17,006	26,942	28,020	33,000	2.0	0.2	1.1	1.1
Brazil	20,111	45,614	59,733	68,567	3.6	1.4	0.9	2.1
Chile	3,803	4,283	2,611	1,724	0.5	-2.4	-2.7	-1.4
Colombia	2,440	5,084	4,834	3,462	3.2	-0.3	-2.2	0.6
Honduras	756	1,589	1,953	1,439	3.3	1.0	-2.0	1.1
Mexico	19,928	23,567	26,900	27,643	0.7	0.7	0.2	0.6
Panama	220	544	662	695	4.0	1.0	0.3	2.0
Peru	1,600	3,174	4,051	4,430	3.0	1.2	0.6	1.8
Uruguay	1,448	1,429	1,325	1,660	-0.1	-0.4	1.5	0.2
Venezuela	2,676	3,488	3,365	3,367	1.2	-0.2	0.0	0.4
Latin America	69,986	115,713	133,454	145,986	2.2	0.7	0.6	1.3

Triennal averages, except 1950. For more details, see appendix.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

Table 4.3 shows the use of land in Latin American agriculture. The cultivated land area increased throughout the entire period. The Latin American pattern resembles that followed in the developing world and contrasts with that of the developed countries, where the agricultural land area decreased in general. The increase in the use of land in Latin American agriculture amounted to 1.3% annually, such that it doubled between 1950 and 2008. Only in Chile did agricultural land decline substantially, while the most important process of expansion took place in Brazil, which more than tripled its cultivated land area. The predominant time pattern was that of a progressive slowing down of the process, with decreasing rates in the three subperiods (2.2%, 0.7% and 0.6%, respectively). Once more, the exceptions were Argentina and Uruguay –and this time Brazil-, with strong rates of expansion in 1990-2008. These cases can be

[74] In our case the principal problem we face is the absence of quantitative data on the use of the new seeds developed on the basis of the Green Revolution. Despite this absence of quantitative data, we shall evaluate their importance when we discuss changes in agricultural productivity.

related to the increase in their crop production and the previously mentioned loss of space destined to livestock production. A part of the increase in the cultivated land area in these three countries is related to the cultivation in new lands of genetically engineered soybeans (Barrows et al., 2014: 102).

The active agricultural population (Table 4.4) grew slightly during the period, although highly diverse behaviours can be appreciated in different countries. In the long term the agricultural manpower only shrank in absolute terms in Argentina and Uruguay. It grew modestly in Brazil, Chile, Honduras and Venezuela, with notable increases in Colombia, Mexico, Panama and Peru. The evolution of the agricultural labour force therefore contrasts with the trajectory followed by the developed countries, with very important falls, but also with the developing countries of Asia and Africa, with very strong increases.

Table 4. 4. Active Population in Agriculture

	Thousands of people				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	1,623	1,448	1,454	1,421	-0.5	0.0	-0.2	-0.2
Brazil	9,887	14,497	14,037	11,622	1.7	-0.2	-1.3	0.3
Chile	648(1)	709	973	969	0.4	1.6	0.0	0.7
Colombia	1,975	2,759	3,503	3,559	1.5	1.2	0.1	1.0
Honduras	538	557	700	670	0.2	1.1	-0.3	0.4
Mexico	4,824	6,942	8,751	8,098	1.6	1.2	-0.5	0.9
Panama	132	202	256	252	1.9	1.2	-0.1	1.1
Peru	1,361(2)	1,864	2,954	3,648	1.4	2.3	1.4	1.7
Uruguay	216(3)	178	195	187	-0.8	0.4	-0.3	-0.2
Venezuela	705	752	849	745	0.3	0.6	-0.9	0.1
Latin America	21,909	29,908	33,672	31,171	1.4	0.6	-0.5	0.6

(1) Datum calculated for 1950. We have assumed that between 1950 and 1952 the data follows the Argentinian evolution.
(2) Datum calculated for 1950. We have assumed that between 1950 and 1952 the data follows the aggregate of Honduras and Mexico evolution.
(3) Datum calculated for 1950. We have assumed that between 1950 and 1960 the data follows the Argentinian evolution.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

Practically all the growth of the agricultural labour force took place between 1950 and 1990, with the abovementioned exceptions of Argentina and Uruguay. From then on the labour force employed fell gently, or remained stable, except in Peru, where it continued to increase, although more slowly, due to the improved

distribution of land from the end of the 1960s (agricultural reform) and flexibilisation in the hiring of labour power from the 1990s on.

To obtain an approximate view of the evolution of the capital employed, we shall use two of its principal components of a fixed nature –livestock head and the use of agricultural machinery- and fertilisers and chemical manure for that of a circulating character.

The increase in livestock was spectacular (Table 4.5), since its number of head doubled throughout the period, at an annual rate of over 1.3%. Brazil (2%) and Venezuela (1.8%) were those countries which grew most, tripling their stock of live animals in the second half of the twentieth century and the beginning of the twenty-first. In the opposing case are those countries, Argentina and Uruguay, which in 1950 already had a greater specialisation in livestock, where growth was much lower (0.1% and 0.3% annually).

Table 4. 5. Livestock units

	Thousands of livestock units				Annual growth rates (%)			
	1950(1)	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	49,196	52,680	49,749	52,943	0.3	-0.3	0.4	0.1
Brazil	60,609	88,936	152,263	192,982	1.7	2.7	1.6	2.0
Chile	3,366	4,105	4,400	4,853	0.9	0.3	0.7	0.6
Colombia	14,582	20,483	25,165	27,035	1.5	1.0	0.5	1.1
Honduras	1,096	1,770	2,273	2,831	2.1	1.3	1.5	1.6
Mexico	22,008	35,309	44,305	47,489	2.1	1.1	0.5	1.3
Panama	643	1,266	1,465	1,689	3.0	0.7	1.0	1.7
Peru	5,422	8,582	8,473	11,461	2.0	-0.1	2.0	1.3
Uruguay	9,649	10,056	11,059	11,569	0.2	0.5	0.3	0.3
Venezuela	5,767	8,636	13,464	16,430	1.8	2.2	1.3	1.8
Latin America	172,338	231,823	312,616	369,282	1.3	1.5	1.1	1.3

(1) Average data calculated by FAO for the period 1948-1952. The rest of the years, triennial averages.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

Latin America was not removed from the process of mechanisation taking place in this period. Table 4.6 shows the sharp growth in the use of tractors, with annual increases of 4.7% in Latin America as a whole. The country which most increased the use of machinery was Brazil, with an annual rate of over 7%.

Until 1990 the increase in the use of tractors was very fast, especially until 1973, with an annual rate of increase of 8.2%, coinciding with the time of their great diffusion in the world. Until 1990 it continued to rise, to then grow very

slowly between 1990 and 2000, and to stagnate from the latter year on. This trajectory could reflect the slower rate of incorporation of tractors into agriculture once they had had a significant diffusion, but it is also undeniable that the most recent are more powerful, which could question the decrease in the process of mechanisation towards the end of the century.

Table 4. 6. Agricultural tractors

	Units				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	25,000	178,220	259,500	238,825	8.9	1.9	-0.6	4.0
Brazil	15,000	218,500	766,260	788,053	12.4	6.5	0.2	7.1
Chile	5,970	34,150	40,974	53,915	7.9	0.9	1.8	3.9
Colombia	6,500	23,868	27,000	20,413	5.8	0.6	-1.8	2.0
Honduras	244	2,479	4,851	5,055	10.6	3.4	0.3	5.4
Mexico	32,000	95,733	307,503	238,830	4.9	6.0	-1.7	3.5
Panama	399	3,307	5,642	7,797	9.6	2.7	2.2	5.3
Peru	2,400	11,350	12,933	12,822	7.0	0.7	-0.1	2.9
Uruguay	10,500	30,570	33,000	36,465	4.8	0.4	0.7	2.2
Venezuela	3,925	23,302	49,000	47,630	8.1	3.8	-0.2	4.4
Latin America	101,938	621,478	1,506,663	1,449,805	8.2	4.5	-0.3	4.7

Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

Table 4. 7. Mechanization intensity

	Tractors per 1,000 workers				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	15	123	178	168	9.5	1.9	-0.4	4.2
Brazil	2	15	55	68	10.5	6.6	1.5	6.8
Chile	9	48	42	56	7.5	-0.7	1.9	3.1
Colombia	3	9	8	6	4.3	-0.6	-2.0	1.0
Honduras	0	4	7	8	10.4	2.2	0.6	5.0
Mexico	7	14	35	29	3.2	4.8	-1.2	2.6
Panama	3	16	22	31	7.6	1.5	2.3	4.1
Peru	2	6	4	4	5.5	-1.6	-1.5	1.2
Uruguay	49	171	169	195	5.6	-0.1	0.9	2.4
Venezuela	6	31	58	64	7.8	3.2	0.7	4.3
Latin America	5	21	45	47	6.7	3.9	0.3	4.0

We have used previous data for tractors and active population.

Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

The ratio of tractors to each thousand workers (Table 4.7) also shows the importance of the acquisitions of machinery by farms, with growth of over 4%

annually for the region as a whole. Identifying this indicator with the degree of mechanisation of agriculture, there can be observed, as above, a progressive deceleration of the process, from its most dynamic phase between 1950 and 1973 (6.7%) until a very moderate growth of 0.3% between 1990 and 2008. Particularly notable cases are those of Argentina and Uruguay, which presented levels above even the Mediterranean countries or Eastern Europe until 1950 (with over 15 and 48 tractors per 1,000 workers, respectively). All the countries registered increases in their degree of mechanisation in the period and their dispersion fell,[75] although the leaders at the middle of the twentieth century continued to be so at the beginning of the twenty-first. In 2008 were notable, in addition to the traditional leaders, Argentina and Uruguay, Venezuela (60.4) and Brazil (59.9) which had had significant rates of expansion. The strategy of the diverse Venezuelan governments, with the exception of the periods of falling oil incomes and economic crisis, has been to encourage agricultural production via massive transfers (subsidised loans, price controls, technical transfers, etc.). The result has been the development of a modern agriculture, intensive in the use of fertilisers and agricultural machinery which, nevertheless, displays a model of expansion highly vulnerable insofar as it depends on state support and protectionist policies (Gutiérrez, 1997). In the case of Brazil agriculture has historically been guided by policies aimed at exports (Mendali et al., 2013), and already by the 1960s the strategy of import substitution was created to settle the bases of capital formation and industrialisation which would give rise to the modernisation of the agricultural sector through fertilisers, chemical products and the manufacture of agricultural machinery. This constituted the first phase in the transformation of Brazilian agriculture (Baer, 2008), and was followed by a second stage, towards the 1960s and 1970s, when the economy continued to advance in the expansion of exports of processed and semi-processed agricultural products (Mendali et al., 2013) and the instrumentation of diverse plans of agricultural research and development (Graham et. al, 1987).

The evolution of the use of chemical fertilisers complements this perspective (Table 4.8). With an average annual rate of growth for the region of 7.7%, generalised growth can be observed around the average, with the sole

[75] The variation coefficient fell from 1.52 in 1950 to 1.04 in 2008.

exception of Peru (3%) and Panamá (4.8%). The growth in the employment of chemical fertilisers, like that of machinery, was concentrated in the initial decades of the second half of the twentieth century, especially between 1950 and 1973 (12.7% annually), the rate of expansion reducing in the following decades (although annual rates of above 4% were maintained).

Table 4. 8. Chemical fertilizers

	Tonnes				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	17,119	76,033	334,367	1,308,867	6.7	7.7	9.5	7.8
Brazil	45,559	1,747,633	4,329,133	9,672,333	17.2	4.6	5.5	9.7
Chile	61,192	169,467	370,000	480,000	4.5	4.0	1.8	3.6
Colombia	21,617	251,333	508,033	679,567	11.3	3.6	2.0	6.1
Honduras	1,800 (1)	22,200	41,723	120,048	11.5	3.2	7.3	7.5
Mexico	22,677	782,833	1,618,600	1,605,667	16.6	3.7	-0.1	7.6
Panama	1,400 (1)	25,372	32,542	21,145	13.4	1.3	-2.8	4.8
Peru	7,021	109,633	131,333	313,200	12.7	0.9	6.0	6.8
Uruguay	2,947	59,200	78,400	159,167	13.9	1.4	4.8	7.1
Venezuela	2,026	95,900	283,333	344,567	18.3	5.6	1.3	9.3
Latin America	183,359	3,339,606	7,727,464	14,704,560	13.4	4.3	4.4	7.9

Triennial averages.
(1) Datum for 1950 to nitrogenous fertilizers and for 1952 for potash and phophorus.
Source: Own elaboration with data from IFA (2014) and FAO (1948-2004). For Honduras and Panama, the data are from FAOSTAT (2012) and FAO (1948-2004). The Peruvian datum for 1950 is from Hopkins (1981). For more details of the sources and for the calculation, see the appendix.

The level of the use per hectare of fertilisers (Table 4.9) also shows the sharp increase in their employment, with increases in this ratio of 6.3% annually for Latin America as a whole. Peru clearly stands out with regard to its level of consumption of fertilisers per hectare in 1950. Its growth, however was the lowest in the entire continent.

Nevertheless, it is convenient to take into account that the Latin American panorama is highly heterogeneous, in both levels and their variations. Towards 2008, dispersion was great and, for example, the quantity of fertilisers per hectare in Chile was 10 times that of Argentina. With regard to their variation, in the subperiod 1990-2008, high growth rates –such as those of Argentina (11%) and Honduras (9.9%)– alternated with decreases in the indicator (as in Mexico and Panama). The evolution of this indicator is closely related to the endowment of natural resources (type and quality of the land) and to the productive

specialisation of each economy; thus, the deep-rooted differences displayed by Latin America in this field are clearly expressed in this technical coefficient.

Table 4. 9. Chemical fertilization intensity

	Tonnes per 1,000 hectares				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	1	3	12	40	4.6	7.5	8.3	6.5
Brazil	2	38	72	141	13.1	3.2	4.5	7.4
Chile	16	40	142	278	4.0	6.6	4.6	5.0
Colombia	9	49	105	196	7.8	3.8	4.3	5.5
Honduras	2	14	21	83	8.0	2.1	9.5	6.3
Mexico	1	33	60	58	15.8	3.0	-0.2	7.0
Panama	6	47	49	30	9.0	0.3	-3.2	2.7
Peru	4	35	32	71	9.4	-0.3	5.3	4.9
Uruguay	2	41	59	96	14.0	1.8	3.3	6.9
Venezuela	1	27	84	102	16.9	5.8	1.3	8.8
Latin America	3	29	58	101	11.0	3.5	3.8	6.5

Triennial averages, except for the data of the land in 1950 and the fertilizers in 1950 for Honduras and Panama.
Source: the same than the tables 2 and 7.

4.4 The productivity of labour and land

Having examined the evolution in the use of agricultural inputs, it is possible to take a step forward and analyse the behaviour of the labour productivity of the land and thereby attempt to see if it is possible to characterise a Latin American model of agricultural change.

To analyse the evolution of the partial productivities of labour and land, we use the identity relationship of Hayami and Ruttan (1985), in which:

$$\frac{Y}{L} \equiv \frac{A}{L} . \frac{Y}{A}$$

where :

Y: *output*,

A: land,

L: labour.

The first terms represents agricultural labour productivity (*Y/L*), which can be interpreted as proportional to land productivity (*Y/A*), in accordance with the land/labour ratio.

If we begin with the productivity of agricultural labour, we can observe that its growth was notable throughout the second half of the twentieth century, with an annual rate of increase of 2.4% which, additionally, accelerated during the period (Table 4.10). That is to say, labour productivity increased its rate of expansion with the passage of time, from a modest rate of 1.5% in 1950-1973, to 2.2% in 1973-1990 and 3.7% en 1990-2008.

Table 4. 10. Agricultural labour productivity

	Production ($ 2004-2006 prices) per worker				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	7,510	9,858	13,402	21,372	1.2	1.5	3.2	1.8
Brazil	836	1,428	2,971	6,861	2.4	3.7	5.7	3.7
Chile	2,263	2,774	4,044	5,995	0.9	1.9	2.7	1.7
Colombia	1,509	1,906	2,652	3,633	1.0	1.7	2.1	1.5
Honduras	708	1,528	1,953	3,276	3.4	1.2	3.5	2.7
Mexico	925	2,044	2,732	4,356	3.5	1.5	3.2	2.7
Panama	1,761	2,445	3,061	5,130	1.4	1.1	3.5	1.9
Peru	964	1,142	942	1,727	0.7	-1.0	4.1	1.0
Uruguay	5,612	7,362	8,648	13,483	1.2	0.8	3.0	1.5
Venezuela	2,209	5,528	8,694	14,712	4.1	2.3	3.6	3.3
Latin America	1,554	2,185	3,336	6,012	1.5	2.1	4.0	2.4

Triennial averages for the production.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

The dispersion of the levels of labour productivity among the Latin American countries has been enormously high throughout the second half of the twentieth century. Argentina and Uruguay had by 1950 very high levels compared to the remaining countries, while Chile, Venezuela and Panama were located at intermediate levels, somewhat above the average for the region, while all the others were clearly below. The evolution of labour productivity in the second half of the twentieth century consolidated the advantage of the countries with high productivity (Argentina, Uruguay and Venezuela). On the other hand the case of Brazil is notable, which most increased its labour productivity, at an annual rate of 3.7%, meaning that it ceased to be one of the countries of lowest productivity to become located above the regional average.

Land productivity also increased throughout the second half of the twentieth century and the early years of the twenty-first, although it did so at a rate lower than that of labour productivity; the annual average was 2% (Table

4.11). As with the latter, the pattern was of progressive acceleration, with rates of 1.5%, 2% and 2.7% for each of the subperiods considered. That is to say, not only did the use of land increase in Latin America but also it was increasingly productive, given the intensification of its use (Solbrig, 2006).

Differences among countries, although important, were fewer than in the case of labour productivity. In this case it was above all Chile, Mexico and Venezuela which stood out for their rapid growth.

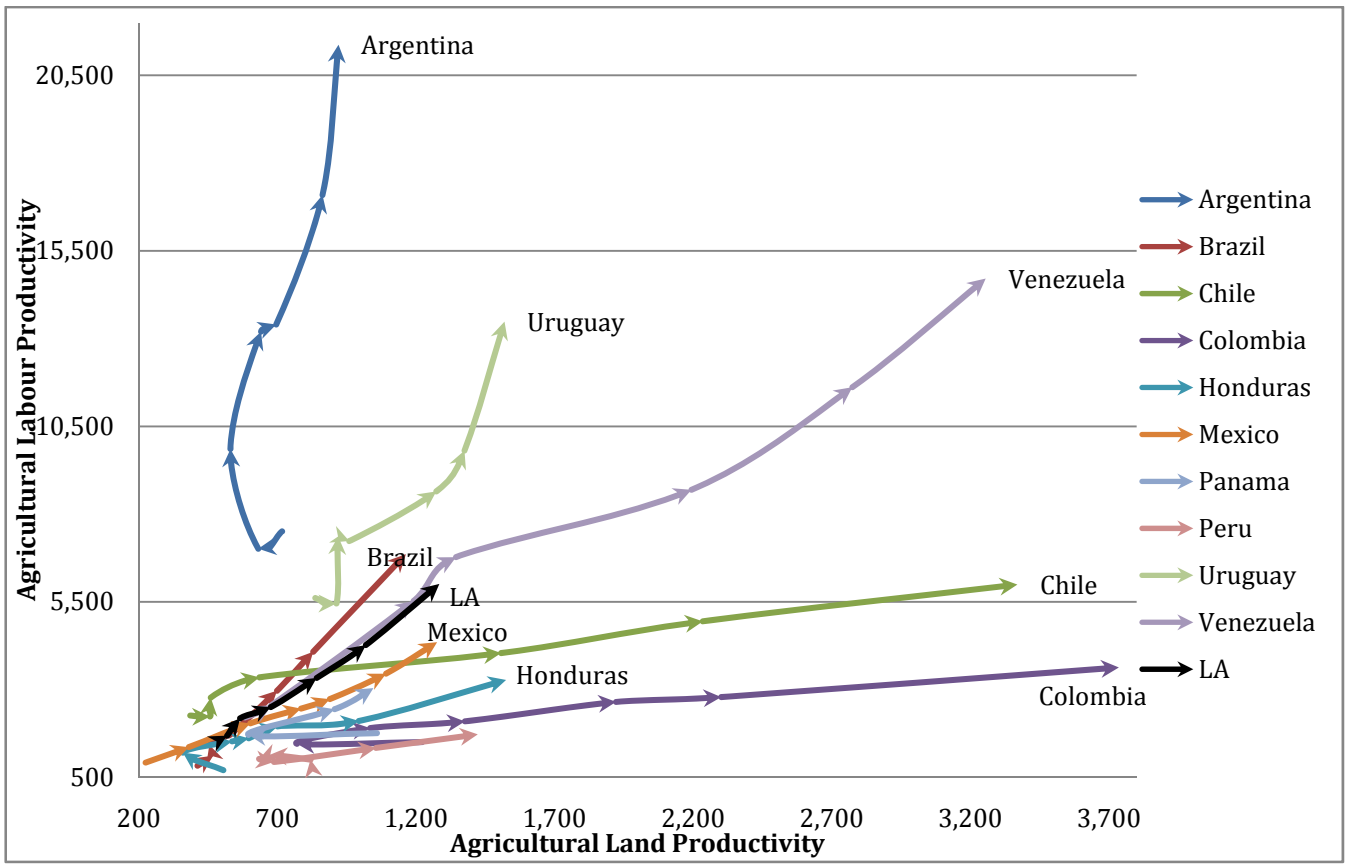
Table 4. 11. Agricultural land productivity

	Production ($ 2004-2006 prices) per hectare				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	717	530	695	920	-1.3	1.4	1.9	0.4
Brazil	411	454	698	1,163	0.4	2.2	3.5	1.8
Chile	385	459	1,507	3,370	0.8	6.1	5.5	3.8
Colombia	1,221	1,035	1,922	3,736	-0.7	3.1	4.5	1.9
Honduras	504	536	700	1,525	0.3	1.3	5.3	1.9
Mexico	224	602	889	1,276	4.4	2.0	2.4	3.0
Panama	1,059	906	1,184	1,860	-0.7	1.3	3.1	1.0
Peru	820	671	687	1,422	-0.9	0.1	5.0	1.0
Uruguay	836	919	1,273	1,519	0.4	1.6	1.2	1.0
Venezuela	582	1,191	2,194	3,256	3.2	3.1	2.7	3.0
Latin America	487	565	842	1,284	0.6	2.0	2.9	1.7

Triennial averages, except for the land in 1950.
Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

If we compare the levels and variation of the two types of productivity, it can be observed that the countries which had the highest levels of labour productivity towards 1950 did not have especially high levels of land productivity. This was the norm throughout the period and, in fact, in some cases the correlation was negative (as in 1950 and 2008). In turn, and as was to be expected, the positive relationship between the two types of productivity is narrow for the countries considered individually (with linear coefficients of between 0.90 and 1), although with different characteristics. Graph 4.2 depicts the relationship between labour productivity (left-hand axis) and land productivity (right-hand axis) for the ten countries and Latin America as a whole.

Graph 4. 2. Agricultural labour productivity vs. Agricultural land productivity



Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

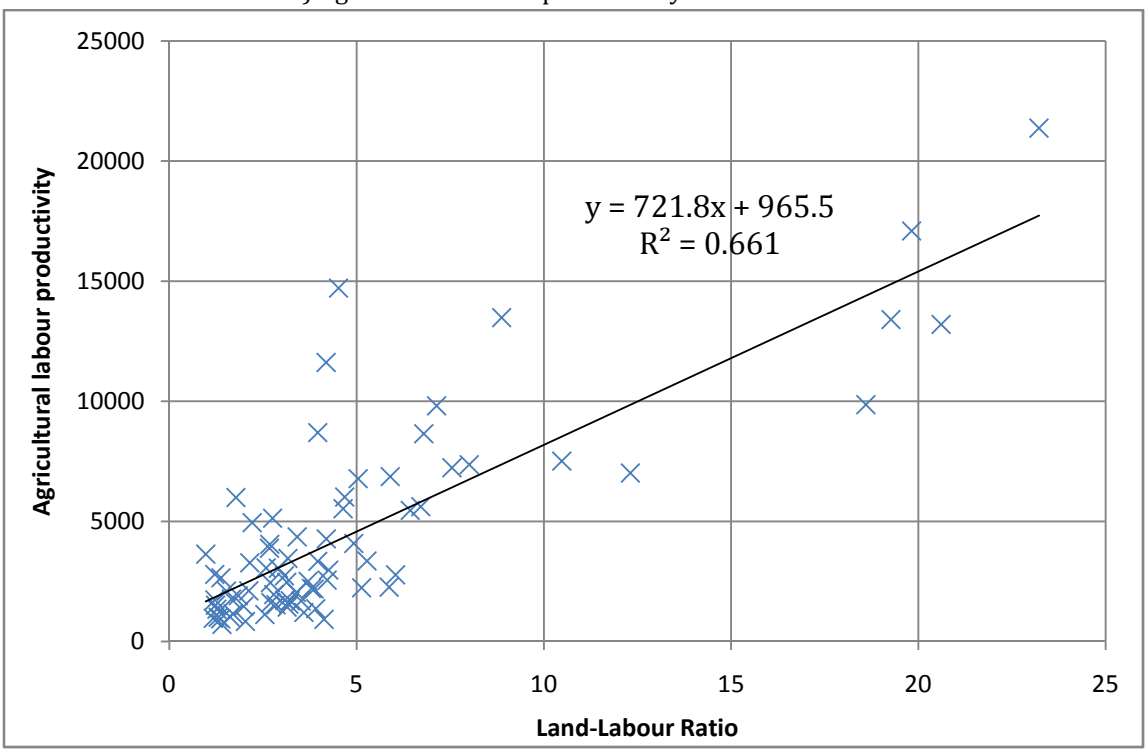
Comparison with the line of Latin America (the darkest) permits two patterns to be visualized. Above the adjustment line are located the countries in which the land-labour coefficient is greater; that is to say, those economies n which the use of land is relatively more intense than that of the productive factor of land (where more land per unit of labour is used). There are two countries which clearly display that characteristic –Argentina and Uruguay–, one which tends to be oriented in that direction –Brazil– and another which abandons that group –Chile. The remaining countries have a pattern based on the more intensive use of labour. The graph shows that the differences are more important in the levels of labour productivity than in land productivity.

4.4.1 Land-labour ratio and evidence of technical change

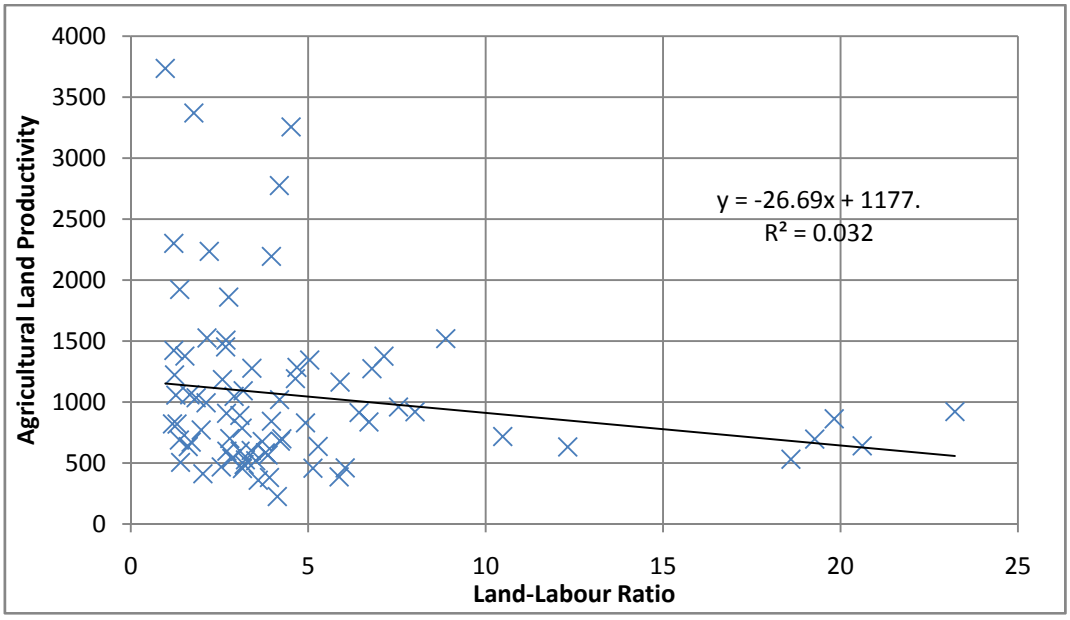
It is also clear that the countries with greater land-labour ratios have higher levels of agricultural labour productivity and a scanty land productivity. Graph 4. 3 represents, *vis-a-vis,* the relationship between the two variables. While this is

narrow in the case of labour productivity (Panel a), it is almost insignificant (and negative) in the case of land productivity (Panel b). This evidence coincides with that presented by Sharma et al. (1990), with regard to the relationship between partial productivities and the land-labour ratio and which indicates that the greater is the provision of land per unit of labour, the greater is labour productivity in Latin American agriculture.

Graph 4. 3. Partial productivities vs. Land-Labour Ratios.
Panel a) Agricultural labour productivity vs land-labour ratio



Panel b) Agricultural land productivity vs land-labour ratio.



Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

Table 4. 12. Land-labour ratio

	Hectares per worker				Annual growth rates (%)			
	1950	1973	1993	2008	1950-1973	1973-1993	1993-2008	1950-2008
Argentina	10	19	19	23	2.5	0.2	1.3	1.4
Brasil	2	3	4	6	1.9	1.5	2.2	1.9
Chile	6	6	3	2	0.1	-4.0	-2.7	-2.0
Colombia	1	2	1	1	1.8	-1.4	-2.3	-0.4
Honduras	1	3	3	2	3.1	-0.1	-1.7	0.7
Mexico	4	3	3	3	-0.8	-0.5	0.7	-0.3
Panama	2	3	3	3	2.1	-0.2	0.4	0.9
Peru	1	2	1	1	1.6	-1.1	-0.8	0.1
Uruguay	7	8	7	9	0.8	-0.8	1.8	0.5
Venezuela	4	5	4	5	0.9	-0.8	0.9	0.3
Latin America	3	4	4	5	0.8	0.1	1.1	0.7

Source: Author's elaboration, from FAOSTAT (2012) and FAO (1948-2004).

The land-labour ratio is a technical coefficient which, in the absence of important technological changes, is not modified significantly. This is the case of Latin America, where it increased by only 0.3% throughout the entire period (Table 4.12). However, the evolution of this ratio is important, since it hardly rose in 1950-1973 (0%) and 1973-1990 (0.1%) to increase by almost 1% per year in 1990-2008. This demonstrates a process of modifications in the way of using land and labour which has only been evident from the 1990s until 2008. The greatest divergences from the average corresponded to Chile and Brazil, although they followed opposite directions. While the ratio fell by almost 3% in the first case – which denoted an increasing intensity of the labour factor– it increased by almost 2% in the second, in a process typical of an economy which even in the course of the second half of the twentieth century could be considered as having open borders. At the end of the 1980s, Brazil promoted a political strategy of extension of the free market, with the elimination of taxes on exports and price control mechanisms, which confronted agriculture with new challenges. Until then, agricultural production had fundamentally been stimulated by the greater use of inputs and, especially, by the occupation of new regions of the centre-west of the country (Garcia et. al, 2010). In fact, in the mid 1980s, public policy moved towards reform movements in the ownership of the land, with the aim of alleviating the problems of rural poverty, including mechanisms of subsidised loans, research and extension services. But this type of extensive growth gave place to another of a

more intensive character, with a predominance of productivity gains which involved improvements in the qualification of the labour force, increases in the operational capacity of machinery and greater expenditure on research and development applied to the land. The confirmation of these processes is contained in the next section. Anyway, and despite the affirmation of substantial improvements in agricultural productivity (even when compared with countries on the technological frontier, such as the United States), there persist serious problems of structural heterogeneity (Fornazier and Ribeiro, 2013).

4.5 Total Factor Productivity: Does a Latin American Pattern exist?

4.5.1. Calculation methodology

Total factor productivity (TFP) is a good indicator to approximate a measurement of the efficiency of the agricultural sector and, in this case, to evaluate its comparative evolution between Latin American countries. The measurement proposed follows the methodology of growth accounting. This productivity is based on the primary definition of the Solow residual, that is to say, it is calculated as the difference between the growth of output and of a combination of productive factors. In the present analysis, this combination is formed by the land factor, comprised of an aggregation of rainfed and irrigated land (arable hectares of land and permanent crops) and irrigated land –in accordance with Fuglie (2010 and 2012)–, labour and capital, which is comprised of chemical fertilisers, self-propelled machinery and livestock units[76]. This combination is a weighted average in which the weightings used are those which appear in Tables 4.A1 and 4.A2 of the Appendix and are the remunerations each factor receives in percentage terms over total production (Del Gatto et al., 2011). We have applied to Argentina and Uruguay the weighting of Argentina, to Mexico, Honduras and Peru that of Mexico, and to the rest that of Brazil.

[76] The estimation of the growth of capital is performed on the basis of the rates of capital for which we have data (tractors, fertilisers, livestock units), which involves assuming that the growth in the rates of capital not considered (principally new seeds or insecticides) was produced at the same rate as for those for which we do have information.

The formula employed to obtain the growth of TFP is that used by Fuglie (2010 and 2012):

$$\ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right) = \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \sum_i\left(s_{i,j,t}\right) \cdot \ln\left(\frac{x_{i,j,t}}{x_{i,j,t-1}}\right),$$

where:

Y and *X* are vectors*; s*: weightings; *i*, countries ; *j*, inputs. i=1,…, 10; j=1,…,5

4.5.2. Inputs contribution and evolution of TFP.

Table 4.13 shows the rates of growth of production, the inputs and the agricultural productivity of Latin America and of the countries analysed.

Table 4. 13. Annual average logarithmic rates between 1950 and 2008

	Production	Labour	Land	Capital	TFP
Argentina	1.68	-0.23	1.13	3.66	-0.04
Brazil	3.97	0.28	2.23	4.57	1.90
Chile	2.46	0.69	-0.55	2.34	1.51
Colombia	2.55	1.01	0.98	2.01	1.19
Honduras	3.04	0.38	1.15	3.69	0.98
Mexico	3.67	0.89	0.77	3.22	1.99
Panama	2.99	1.11	2.03	2.78	1.26
Peru	2.70	1.70	1.17	2.49	1.13
Uruguay	1.13	-0.25	0.48	2.31	0.23
Venezuela	3.46	0.10	0.68	3.58	2.22
AL BRA	3.01	0.61	1.33	3.26	1.43
AL MEX	3.01	0.61	1.33	3.41	1.04
AL ARG	3.01	0.61	1.33	3.87	0.93

AL BRA, Latin America with the Bazilian shares in the capital and TFP calculation; AL MEX, Latin America with the Mexican shares in the capital and TFP calculation; AL ARG, Latin America with the Argentinian shares in the capital and TFP calculation. The capital growth rate for this table and subsequents is a weighted average of the growth rates of fertilizers, machinery and livestock. We have used as shares the same than for the calculation of the TFP, butfor these tables these three weights sum to 1.
Source: Author's elaboration, from FAOSTAT (2012), FAO (1948-2004) and IFA (2014).

The sharp rate of growth (almost 3% annually) was principally driven by the incorporation of factors into the productive process, although the most notable role was that of capital, which expanded by 4.5%, while TFP hardly increased above the use of the labour productive factor (0.7%). The strong capitalization of Latin American agriculture was an extended feature throughout the region. The contribution of TFP was modest in the region, although very significant differences

are to be found. Thus, the leading economies in the increase of productive efficiency were Venezuela, Mexico and Brazil, with increases of 2.2%, 2% and 1.9%. The only countries to distance themselves significantly from the Latin American average were Uruguay and Argentina, where the rates of variation of TFP were very low for the former country and negative for the latter. The remaining countries had values very close to the regional average. To better visualize the evolution of these indicators we shall analyse them separately for the three subperiods into which we have divided the years 1950-2008.

Table 4. 14. Annual average logarithmic rates between 1950 and 1973

	Production	Labour	Land	Capital	TFP
Argentina	1.21	-0.49	1.97	4.17	-0.71
Brazil	4.24	1.66	3.59	6.52	0.83
Chile	1.69	0.39	0.34	3.54	0.61
Colombia	2.73	1.45	3.31	3.84	0.11
Honduras	3.49	0.15	3.30	6.55	0.04
Mexico	5.35	1.58	1.02	5.49	3.01
Panama	3.43	1.84	3.94	5.88	-0.04
Peru	2.16	1.37	1.79	5.23	-0.36
Uruguay	0.21	-0.83	0.06	3.70	-0.84
Venezuela	4.46	0.28	1.50	5.65	2.56
AL BRA	3.14	1.35	2.17	4.76	0.74
AL MEX	3.14	1.35	2.17	5.57	0.26
AL ARG	3.14	1.35	2.17	5.65	-0.01

AL BRA, Latin America with the Bazilian shares in the capital and TFP calculation; AL MEX, Latin America with the Mexican shares in the capital and TFP calculation; AL ARG, Latin America with the Argentinian shares in the capital and TFP calculation.
Source: Same sources as table 15.

The growth in the use of capital registered its highest rate during the stage identified with the ISI and the contribution of TFP was the lowest of all the period analysed (less than half a percentage point). That is to say, the period of industrialisation induced by the state showed, in the agricultural and livestock sector, growth of an extensive nature and which barely supported itself on efficiency improvements (Table 4.14). Furthermore, these were very different among countries throughout the entire period, alternating very high rates –such as Mexico (3.0%) and Venezuela (2.6%) –with others almost non-existent –such as

Honduras or Colombia– or negative –as in Peru, Uruguay, Panama and Argentina. The panorama changed sharply in the following stage.

Between 1974 and 1993 and, in contrast to the foregoing subperiod, despite agricultural output increasing at a slightly lower rate, the contribution of productivity was greater (Table 4.15). In this subperiod no negative variations in productivity were recorded and Chile (1.9%), Colombia (1.5%) y Brazil (1.9%), Venezuela (1.7%) stood out with increases above the average, Mexico falling visibly as its efficiency improvements were almost imperceptible.

Table 4. 15. Annual average logarithmic rates between 1974 and 1993

	Production	Labour	Land	Capital	TFP
Argentina	1.44	0.02	0.21	3.03	0.07
Brazil	3.44	-0.16	1.54	4.10	1.89
Chile	3.11	1.58	-1.15	1.94	1.87
Colombia	2.62	1.19	0.28	1.56	1.54
Honduras	2.43	1.14	1.16	2.18	0.70
Mexico	2.63	1.16	0.90	3.40	0.19
Panama	2.32	1.20	1.04	1.63	1.11
Peru	1.76	2.30	0.97	0.18	0.97
Uruguay	1.17	0.44	0.01	1.36	0.43
Venezuela	2.95	0.61	0.14	3.19	1.67
AL BRA	2.65	0.59	0.88	2.92	1.26
AL MEX	2.65	0.59	0.88	2.91	0.69
AL ARG	2.65	0.59	0.88	3.35	0.83

AL BRA, Latin America with the Bazilian shares in the capital and TFP calculation; AL MEX, Latin America with the Mexican shares in the capital and TFP calculation; AL ARG, Latin America with the Argentinian shares in the capital and TFP calculation.
Source: Same sources as table 15.

Whatever the case, the period of greatest productivity increases was that of the two last decades of the period (1993-2008); this coincides, on the other hand, with the greatest increase in production. In this last subperiod the contribution of TFP was notable, even exceeding the expansion of capital for the Latin American average and for various countries such as Brazil, Colombia, Chile, Honduras, Mexico, Panama, Peru, Uruguay and Venezuela. As in the whole period, the countries with the worst performance in terms of efficiency improvements in agriculture were Uruguay (1.6%) and Argentina (0.8%). This significant increase of TFP coincided with the reduction in the use of the

productive factor of labour, which fell by 0.5% in Latin America on average, in a process which was also followed by Argentina, Brazil, Chile, Honduras, Mexico, Panama, Uruguay and Venezuela. Finally, the contribution of the land factor was highly varied. It moderated its contribution in Latin America as a whole and underwent a decrease in three countries.

Table 4. 16. Annual average logarithmic rates between 1994 and 2008

	Production	Labour	Land	Capital	TFP
Argentina	2.70	-0.15	1.06	3.74	0.84
Brazil	4.28	-1.26	1.04	2.21	3.56
Chile	2.77	-0.03	-1.11	1.05	2.41
Colombia	2.18	0.11	-1.65	-0.20	2.39
Honduras	3.16	-0.29	-2.16	1.33	2.80
Mexico	2.50	-0.52	0.23	-0.50	2.84
Panama	3.20	-0.10	0.44	-0.43	3.46
Peru	4.78	1.41	0.46	1.36	3.61
Uruguay	2.49	-0.28	1.74	1.46	1.61
Venezuela	2.58	-0.87	0.12	0.93	2.42
AL BRA	3.31	-0.51	0.65	1.44	2.72
AL MEX	3.31	-0.51	0.65	0.76	2.72
AL ARG	3.31	-0.51	0.65	1.84	2.50

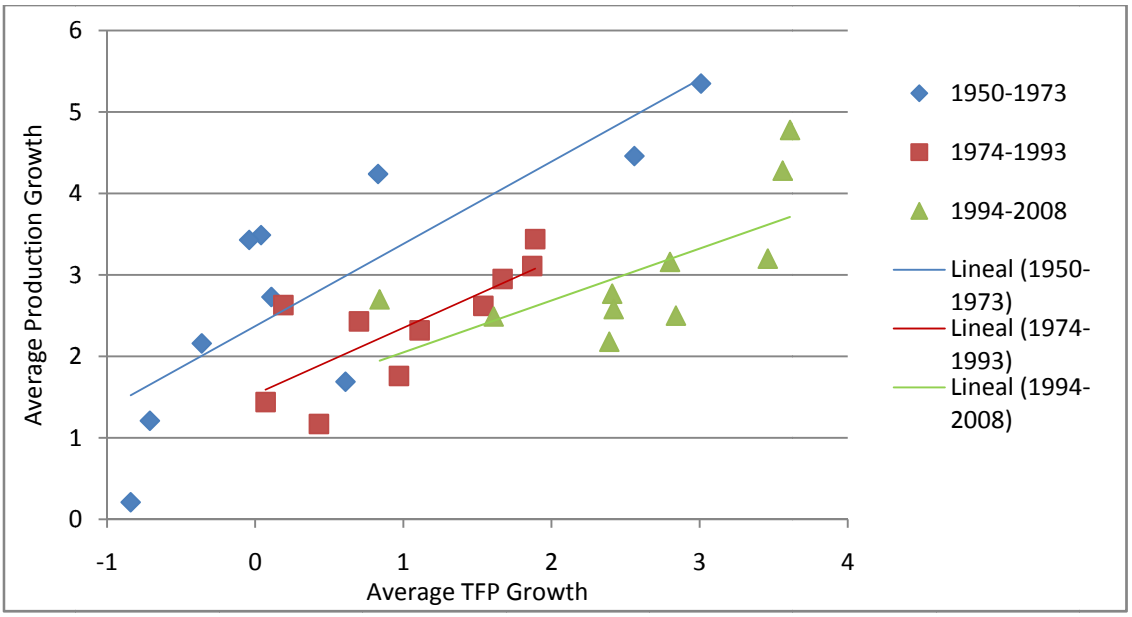
AL BRA, Latin America with the Bazilian shares in the capital and TFP calculation; AL MEX, Latin America with the Mexican shares in the capital and TFP calculation; AL ARG, Latin America with the Argentinian shares in the capital and TFP calculation.
Source: Same sources as table 15.

The relationship between the variation in output and in TFP is close throughout the period (see Graph 4. 4), which makes clear the strong link between improvements in productive efficiency and the expansion of production. Furthermore, the rightward movement of the trend lines shows that a greater increase in TFP was increasingly necessary to obtain the same growth in production. The countries of the Southern Cone occupy positions of low growth in production and limited efficiency improvements, a pattern from which Chile and Peru seem to "escape" in the final subperiod, to place themselves in the quadrant of strong growth and high TFP. Both Mexico and Venezuela started with strong increases in production and TFP, to then lower their rates and, finally, recover strong growth of TFP but a weaker increase of production. Throughout the period Brazil had strong increases in production and an increasingly faster rate of

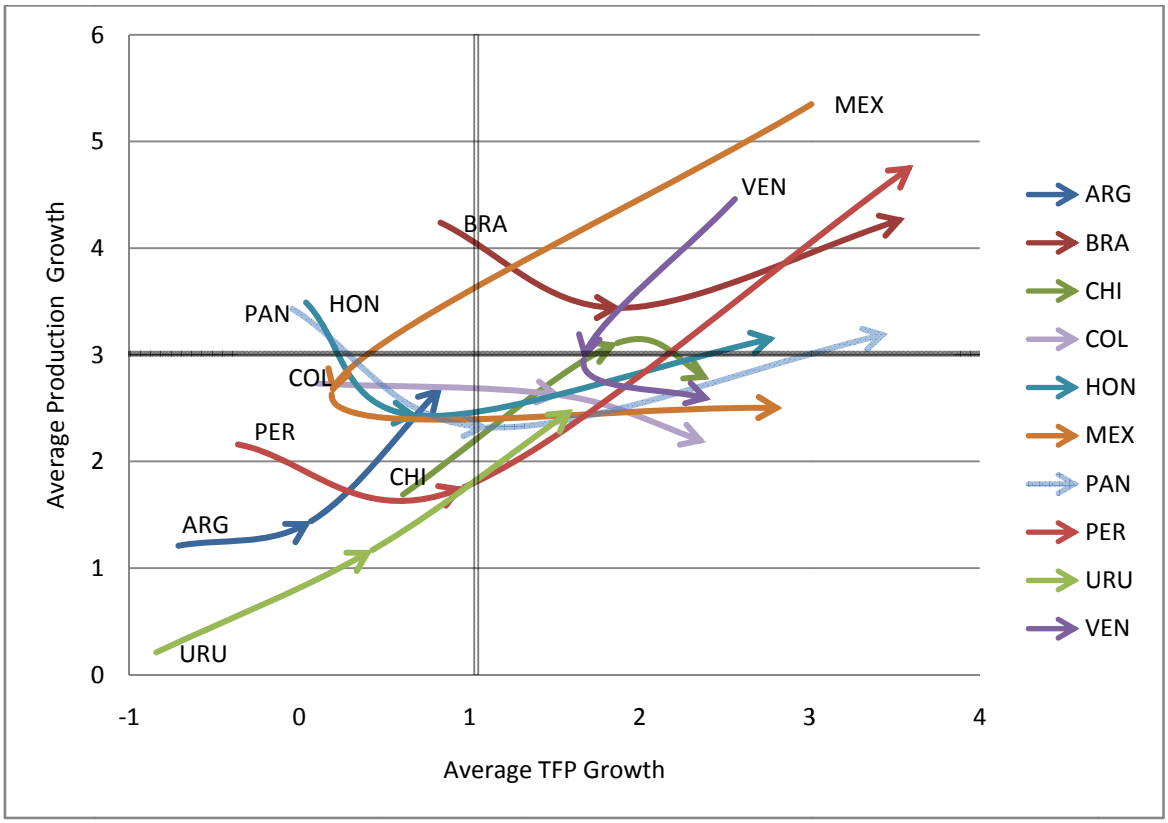
efficiency improvement. That is to say, Brazil would have increased its production by basing itself on an extensive model which only intensified from the 1990s onwards.

Graph 4. 4. Relationship between growth of production and the TFP (1950-1973, 1974-1993, 1994-2008)

Panel a)



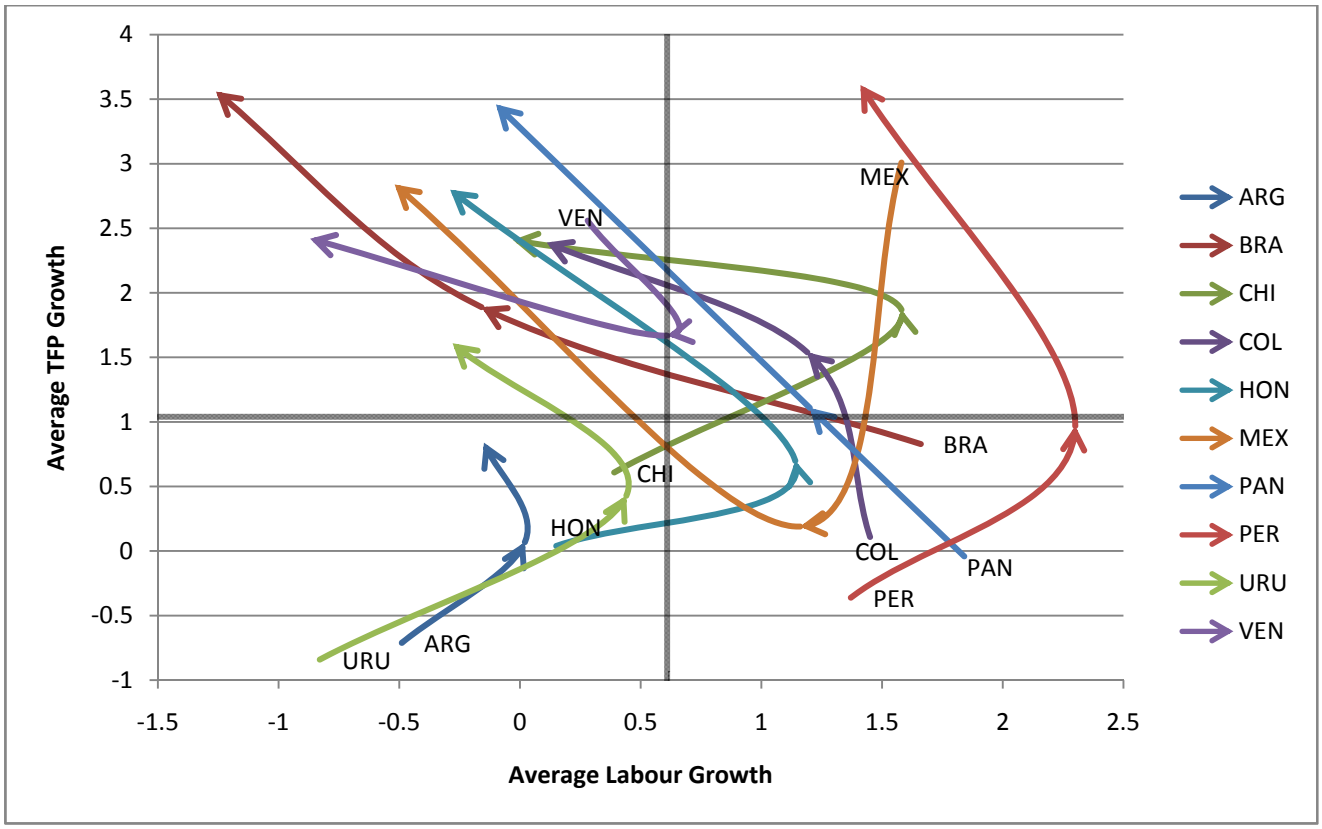
Panel b)



Source: Author's elaboration, from FAOSTAT (2012), FAO (1948-2004) y IFA (2014).

The relationship between the trend of TFP and the labour input confirms the conjectures presented previously with regard to the advent of important technical changes since the 1990s. Graph 4.5 represents the relationship between the increase in TFP and the growth of the labour productive factor.

Graph 4. 5. Average TFP growth vs Average labour growth



Source: Own elaboration FAOSTAT (2012), FAO (1948-2004) y IFA (2014).

Argentina and Uruguay are located in the quadrant of lowest growth in labour and in TFP (lower left-hand quadrant). In turn, the remaining countries moved, with few exceptions, from the quadrant of the highest growth of labour and the lowest of TFP (lower right-hand quadrant) towards a scenario of a decrease of labour and of greater increases in joint productivity of the sector. In this way, the trend throughout the period, principally the final subperiod (1993-2008) was of lower growth or of decrease in some cases in agricultural labour, while a greater growth of TFP was produced.

In other words, the increase in the land-labour ratio, observed in the agriculture of Latin America from the 1990s on, signalled changes in the agricultural production function, characterised by efficiency improvements and a

(relatively) lesser use of the labour input. This process responds to a multiplicity of factors, although three of them seem particularly important: (i) the incorporation of state-of-the-art technology, with the introduction of biotechnology and communication technologies into the agricultural system (ii) the commitment to non-traditional production, with a strong export tendency in increasingly liberalised economies; (iii) the participation of new actors in the agricultural sector, who promoted more competitive forms of agricultural production and of business, in harmony with systems which were successful in other sectors (the "industrialization of agriculture").

Kay (1994) maintains that as part of the process of the globalisation of the economy transnational agricultural corporations and local investors appear preponderantly on the scene of Latin America. With the use of new technology which permitted improvements in the systems of storage, agro-industrial processing, preservation, transport, communications and industrial organisation, these companies had achieved advantages in the production of fruit, vegetables and flowers. The cases of Chile and Peru (and, partially, Brazil and Colombia) are representative of these tendencies. The structural reforms of the 1990s and, in particular, the policies aimed at promoting the development of agri-food industry – together with the advent of free trade treaties- created favourable conditions for non-traditional agricultural exports to expand and become consolidated. Thus, in the period 1990-2008 notable changes were produced in TFP, which were accompanied by a greater commercial opening to the international markets, the increasing worldwide demand for healthy, quality foodstuffs, the incorporation of new lands into agricultural activity, the increasing interest in biofuels, the increase in the income of a population which demanded a more varied supply of high quality foodstuffs, and the expansion of private investment in agriculture. In the temperate zones –such as the Southern Cone- from the 1990s on, the economy embarked upon a stage of strong liberalisation, with a reduction of tariffs and rigid exchange rates which affected the competitiveness of agriculture without receiving special programmes of promotion or support. The challenge was met by important advances in agricultural modernisation, the results of which have given clear indications of structural change, including the expansion of the agricultural frontier in Argentina (Campi, 2008) and various states of Brazil, a greater intensity

in the use of land in the pampas, new forms of production (the "sowing pools", whose star product is soya) and the explosive growth of feedlots.

4.6 Conclusions

In this study we have shown, firstly, that the model of growth of Latin American agricultural production has some typical characteristics which hinder its insertion into the more general pattern of not only the developed countries but also the developing countries. The rapid growth of production fits well within that of the developing countries, while its increase in labour productivity places it at an intermediate level between the lowest of the developing countries and the highest of the developed countries. Furthermore, it has been the only region of the developing world in which the improvement of labour productivity has been based not only on improvements in land productivity but also on the land-labour ratio.

However, the analysis of the diverse Latin American countries offers very important contrasts among them. It is difficult to talk of a common model, but instead of strong variations among the diverse national experiences. If we take into account the contribution to the increase in production of the inputs employed and of TFP, various conclusions may be reached.

Firstly, there took place an increase in production in the period as a whole. This was notably high, at almost 3% annually for 58 years, which meant an increase in production truly notable in absolute terms (production in 2008 was more than five times higher than that in 1950). However, the differences among countries were important. The countries which had most success in basing their model of growth on the first globalisation of agricultural exports, Argentina and Uruguay, were those which grew least, especially due to their poor performance until 1990. Brazil, Mexico and Venezuela were the leaders in growth.

Secondly, this increase was very similar during the stage of ISI and the crisis of the 1970s and 1980s, to then accelerate during the subsequent liberalisation. Here once more there is a sharp contrast with the developed countries and Europe, where production increased significantly until 1985 and then decelerated. The acceleration of growth in Latin America after 1990 is clearly apparent in those countries which had grown least and around those dates returned strongly to the

world market for agricultural products, Argentina and Uruguay. Brazil maintained very high rates throughout the period, and some countries, such as Colombia, Mexico or Venezuela, reduced their speed of growth from those dates onwards.

Efficiency gains made a rather modest contribution to this strong increase in production. Above all, capital was the productive factor which best explains the increase in output. The remaining factors, in contrast to the developed countries and Europe, displayed positive growth. All the above suggests a model of agricultural development very different to that of the developed countries and even to that of the centrally planned European economies.

The differences among the Latin American economies are very significant. Paradoxically, in the countries with a more modern agriculture in 1950, Argentina and Uruguay, the contribution of TFP was lower. Countries which in 1950 continued to have a fairly traditional sector, such as Mexico, Venezuela or Brazil, are those in which the contribution of TFP was greater.

From a time perspective, efficiency gains have made an increasing contribution to the growth of production, being especially significant in the last subperiod, that of the abandonment of ISI policies and the introduction of a greater liberalisation into agriculture.

Appendix

Statistical series

The data employed in this calculation come from the FAO database, both in its electronic version and from its yearbooks (FAO 1948-2004 and FAOSTAT 2012). The production data relate to the gross production, valued in constant US dollars from 2004 to 2006. The land data are an aggregate between the hectares of arable land and permanent crops and hectares that are equipped for irrigation. The agricultural work is measured through the active agricultural population.[77] The machinery is measured through the number of agricultural tractors. The chemical

[77] The correct measurement of the work would have to consider hours worked. The time and space range of the sample makes it necessary to perform the measurement through a proxy, such as the active agricultural population.

fertilisers are the sum of the consumption of nitrogen, potassium and phosphorus fertilisers. The cattle units have been calculated by adding the number of live animals to the weights suggested by Hayami and Ruttan (1989).

We present below some estimates that we had to make.

Land data:

The FAO data from the Production Yearbook for 1950 are not consistent with the literature for Argentina, Chile and Uruguay.

Argentina: we have calculated the arable area for the 1950s by assuming that it follows the same trend as the area sown with the 15 main crops in Argentine agricultural (Ferreres 2005).

Chile: in view of the absence in the census of any comparable figures between 1950 and 1961, we have used the data that appear in FAO (1948-2004) for 1949. Calculating the correlation between the trend followed by the interpolation between the data from 1949 and the data from 1961 and the data on cultivated land about the main Mitchell crops between those years, this is 0.81.

Uruguay: the Uruguayan land data is the number of hectares of the farming land, meadows, vineyards and fruit trees from the 1951 census.

These data are what we have considered for the PTF calculation.

Livestock:

Argentina: Interpolated bovine and caprine data relating to 1950. Data on ducks, geese and turkeys calculated for 1950, continuing the trend followed in the 1960s.

Brazil: Data on ducks, geese and buffaloes calculated for 1950, continuing the trend followed in the 1960s.

Chile: Data on donkeys and mules calculated for 1950, continuing the trend followed in the 1960s.

Colombia: Interpolated caprine data relating to 1950.

Mexico: Data on ducks and geese calculated for 1950, continuing the trend followed in the 1960s.

Panama: Data on chickens, turkeys, mules and interpolated caprine data relating to 1950.

Uruguay and Venezuela: Data from 1950.

Tractors:

For the countries that after 2002 FAOSTAT did not offer agricultural tractor data, we have assumed that they follow the trend set between 2002 and 2006 from an aggregate of countries composed of Brazil, Chile, Mexico and Uruguay. We have assumed that the tractor trend continued between 2006 and 2008.

Fertilisers:

The fertiliser data come from the IFA (International Fertiliser Industry Association, 2014) database from 1961, except for Honduras and Panama, which come from FAOSTAT (2012). For the 1950s, we have assumed that these series progress in the same way as the FAO data (1948-2004). The case of Peru is the only exception, because for the 1950s it followed a similar trend to organic and inorganic fertilisers. In order to correct this conflicting data, we have assumed that Peru continued the trend of chemical fertilisers recorded by Hopkins (1981, 104).

Weights used in the estimate of the TFP

Table 4.A.1 WEIGHTS RELATING TO MEXICO

(Fernández Cornejo and Shumway, 1997)

	Work	Land	Cattle	Fixed capital	Chemicals
1950	0.256	0.489	0.118	0.089	0.048
1973	0.242	0.373	0.200	0.147	0.038
1990	0.117	0.202	0.362	0.289	0.031
2008	0.115	0.225	0.353	0.263	0.045

Source: Own elaboration using data from Fuglie (2012)

Table 4.A.2 WEIGHTS RELATING TO BRAZIL

BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (IBGE)

	Work	Land	Cattle	Fixed capital	Chemicals
1950	0.434	0.342	0.126	0.071	0.027
1973	0.434	0.342	0.126	0.071	0.027
1990	0.429	0.137	0.1745	0.144	0.116

2008	0.373	0.083	0.129	0.161	0.255

Source: Own elaboration using data from Fuglie (2012)

Table 4.A.3 WEIGHTS RELATING TO ARGENTINA

	Work	Land	Cattle	Fixed capital	Chemicals
1950	0.333	0.333	0.188	0.106	0.040
1973	0.340	0.261	0.160	0.122	0.117
1990	0.345	0.207	0.140	0.135	0.174
2008	0.350	0.150	0.118	0.148	0.234

Source: Díaz Alejandro (1975) and Elías (1992)

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Conclusions

This dissertation seeks to identify, analyse and understand the primary long-term trends in agriculture, especially in the second half of the 20th century in Europe and Latin America. Specifically, we study the evolution of the productivity of this sector and the differences that exist among the countries of these two regions.

Throughout this study, we have sought to identify the determinants of agricultural productivity, in the context of the debate about the causes of economic growth and the influence of those causes on agricultural productivity. That productivity experienced unprecedented growth in the period of our study. Among the proximate causes, technical change in the sector was extraordinary because of the rapidity of its large-scale adoption. Simultaneously, there was a massive shift of labour from the agricultural sector to the larger economy, and this structural change reduced the role of agriculture to a level never before seen, with respect to its importance in the economy; meanwhile, agricultural production continued to grow until the mid-1980s. Innovations such as 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, all contributed to high levels of growth in productivity.

Much of this innovation led to the increased importance of capital, to the detriment of the inputs from traditional agriculture, namely, land and labour. Particularly significant is the decline in importance of these factors in Europe, in both absolute and relative terms. Many of the benefits of these changes accrued to improvements in human capital and the quality of labour and this, in turn, played a crucial role in increasing labour productivity and TFP.

As we have seen, fundamental causes have made a remarkable contribution to the explanation of the differences in agricultural productivity. Geography and institutions have long been regarded as significant determinants of differential levels of productivity, and this dissertation (comprising several academic articles) attempts to identify, specifically, the determinants of agricultural productivity in Europe and in Latin America.

In Chapter 1, our model shows that growth in productivity led directly to growth in output. On the other hand, we identify three different patterns of agricultural growth in Europe. The first includes the western European countries, where strong increments in productivity and in input use account for the growth in production. The trend of these variables led to lower growth, explained by stagnation or reduction in input use, and positive growth in productivity, although at a lower rate than in the first decades of the second half of the 20th century. The opposite pattern holds in the Central and Eastern European countries. The incorporation of capital-formation inputs, and low productivity growth account for output growth. After the fall of the centrally-planned economies, these countries reduced the use of technical inputs, sometimes drastically, and slight increments in TFP limit the decreases in output. This pattern also applies to the lesser-developed countries of Southern Europe and the Nordic countries, where capital formation led to more moderate growth in productivity until the mid-1980s. After this period, the trend reverted to the Western pattern, i.e. decreasing or stable reliance on inputs, with productivity being the main source of growth.

In Chapter 2, we analyze the differences in agricultural labour productivity, via an examination of the evolution of land productivity and the land-labour ratio. We also study the trend of the dispersion of labour productivity, which was static, or decreased slightly, in the second half of the 20th century. In our econometric models, the significance of the ratio of land per worker in explaining these variations was remarkable. The processes of structural change led to an increase in the land-worker ratio in Europe. Additionally, the role played by the other proximate causes - irrigation, machinery, livestock, chemical fertilizers, and human capital – was also important. The underlying factors in economic growth also explain the differences, in that those countries with centrally-planned systems had a negative relationship to labour productivity, while in EU-member countries, that same relationship was positive. Geography, primarily in terms of specific bioclimatic zones, was essential to understanding these differences. In our dynamic analysis, the importance of the initial level of labour productivity, as well as the land-labour and machinery-labour ratios, demonstrates the existence of beta-convergence to different steady state levels, determined by these ratios.

Chapter 3 contributes to clarify the importance of fundamental causes, explaining the differences in the agricultural TFP in Europe. Geography was a decisive influence in the differing trends of TFP; the Nordic countries, with colder temperatures, had lower increments, while the Mediterranean countries, despite their aridity, had higher growth rates, primarily from more widespread irrigation and more hours of sunshine.

Regarding the role of institutions, countries with higher levels of civil liberty and political rights had higher growth rates in agricultural productivity. The more commercially open a country, the more positive the relationship to productivity growth. On the other hand, countries enjoying state-sponsored agricultural support policies were detrimental to productivity growth, since such policies allow low-productivity farms - and farmers - to persist. Membership in the European Union, however, did contribute to TFP growth, as did the positive influence of human capital.

Chapter 4 looks at Latin America, concluding that the primary sources of growth there have been the incorporation of capital-formation inputs. This was the case until the 1990s, under Import Substitution Industrialization policies and the subsequent external debt crisis, but from then, and into the first decade of the 21st century, the main source of output growth was TFP, during a time of economic liberalization.

Examining the Latin American pattern and observing agricultural labour productivity and its components - land productivity and the land-labour ratio - we see different patterns. Argentina and Uruguay, countries that in 1950 were the most advanced in the region, maintained high levels of labour productivity in the initial years of the study, with productivity increases being tied to increases in the land-worker ratio. Colombia and Chile saw gains in agricultural labour productivity, arising from growth in their land productivity. Venezuela attained similar results from a balance of both these factors. Brazil began with the same kind of balance, but then evolved to become more akin to the Argentinean pattern.

The research proposed in this dissertation, necessarily, is not an endpoint in the research into the determinants of long-term agricultural productivity. Several issues remain to be expanded and developed.

For example, Spain could not incorporate certain innovations that benefited economic growth in North-western European countries, such as the introduction of legumes in the 19th century, because of its geographical characteristics. Differences in geographical conditions across regions are important in determining levels of development; geographical obstacles of some areas have been overcome, for example, through irrigation, but the impact of this innovation is not uniform across the whole Spanish territory. This opens a line of research to study this development, and others, in terms of causes of productivity grow. Other factors, environmental and geographical, such as temperature, rainfall and orographic conditions, should also be analysed.

Since access to resources is inextricably linked to agricultural productivity, it would also be interesting to have access to some measurement of income, or property-distribution inequalities, in order to study the effects of inequality on agricultural productivity.

In much of this work, we have estimated agricultural TFP via the growth accounting methodology, to observe the trend of productivity. A possible line of research for the future would be to examine productivity using other methodologies, in order to make comparisons among countries, to calculate the determinants of these new measures, and to enhance the robustness of our current estimations.

In Europe, the trend has been to increase the percentage of livestock in total production, while the trend in Latin America has been to decrease this percentage, with both cases affecting the productivity of the sector. The study of changes in the productive structure of agriculture can help to explain not only the determinants of productivity, but also the relationship of some of those factors of economic growth to productivity itself. The different causes of economic growth, the proximate and the fundamental, directly or indirectly affect crop and livestock

production. Therefore, the study of the relationship between these causes and agricultural productivity can also be clarified.

The analysis of sources of growth in agricultural production and productivity can point the way to further study. For example, from 1870s to the Great War, the historical and agricultural context was quite varied. European agriculture was characterized by a growing commercial integration and increased international competition. Some countries elected to protect their products, while other countries favored changes in the productive structure. Against this background, it would be interesting to analyze the differences in agricultural productivity that arose in that period; both technical change and its differential adoption and market potential could have an important role in our understanding of those differences.

Conclusiones

La tesis, que en esta sección finaliza, busca observar, estudiar y comprender las grandes tendencias de la agricultura en el largo plazo, especialmente en la segunda mitad del siglo XX, en Europa y en América Latina. Más concretamente, la tesis estudia la evolución de la productividad de este sector y las diferencias que existen entre los países de estas dos regiones mundiales.

En el estudio de estas diferencias, se busca explicar los determinantes de la productividad en la agricultura de los países europeos y latinoamericanos. La búsqueda de estos determinantes se vincula al debate sobre las causas del crecimiento económico. La distinta influencia en la productividad de la agricultura de los diversos tipos de causas es numerosa, como hemos visto a lo largo de la tesis.

La productividad de la agricultura, que tuvo crecimientos sin precedentes en el período de estudio de la tesis, se ha visto influido por distintos factores. Dentro de las causas próximas, el cambio técnico que se produjo en este sector fue extraordinario, por la rapidez de su adopción masiva, así como por el desarrollo de mejoras de las innovaciones técnicas que llevaban en algunos casos décadas ya en algunos países. Simultáneamente tuvo lugar un trasvase masivo de mano de obra del sector agrario al resto de la economía, que redujo el papel de la agricultura a mínimos históricos en cuanto a la importancia en la economía, mientras la producción agraria no dejó de crecer hasta mediados de la década de los 80. Las innovaciones adoptadas como la maquinaria agrícola, los fertilizantes químicos y pesticidas, la selección genética e hibridación de semillas, el desarrollo de la cría ganadera intensiva, la mejora del crédito agrario y la expansión del regadío en los países mediterráneos, permitieron estos incrementos de la productividad tan elevados.

Muchas de estas innovaciones supusieron un incremento de la importancia del capital, en detrimento de los factores productivos de la agricultura tradicional, es decir, de la tierra y del trabajo. Especialmente relevante es la pérdida de importancia de estos factores en Europa, ya que no sólo descendió de manera relativa, sino también en términos absolutos.

Se pudo aprovechar todo el potencial de estas innovaciones gracias a las mejoras de capital humano que se produjeron en este período. Esta mejora en la calidad del trabajo, por tanto, tuvo un papel relevante en los determinantes de la productividad de la agricultura, tanto en la productividad del trabajo como en la TFP.

Como hemos visto, las causas fundamentales también han tenido un papel remarcable en la explicación de las diferencias de la productividad en la agricultura. La geografía o las instituciones han sido determinantes muy significativos de los distintos niveles de productividad. Con mayor concreción, esta tesis formada por varios artículos académicos obtiene de manera individual en cada uno de ellos respuestas sobre cuáles han sido los determinantes de la productividad de la agricultura en Europa y en América Latina.

En el primer capítulo, las principales conclusiones son dos. Por un lado en Europa, un modelo de crecimiento intensivo explicó el crecimiento del output, es decir, este crecimiento se produjo por incrementos de la productividad más que por aumentos en el uso de los factores. Por otro lado, se han identificado tres diferentes patrones de crecimiento agrario en Europa. El primero sería el característico de los países occidentales de este continente. En éstos, el crecimiento de la producción viene explicado por fuertes incrementos tanto de la productividad como del uso de los factores. La tendencia de estas variables se dirige a un estancamiento productivo, explicado por mantenimientos o reducciones en el uso de los factores y crecimientos positivos, aunque más modestos en la productividad. La antítesis de este primer grupo lo formarían los países del centro y el este europeos, en los cuales el crecimiento del output vendría explicado por fuertes incorporaciones de los inputs que forman el factor capital y en leves incrementos de la productividad. En cambio, estos países después de la disolución del sistema de planificación central redujeron el uso de ciertos inputs técnicos, en ocasiones de manera drástica, y fueron los leves incrementos de la TFP los que permitieron que el decrecimiento del output no fuera mayor. El último patrón lo formarían los países menos desarrollados del sur europeo y los nórdicos. Estos países tuvieron fuertes crecimientos en el uso de los inputs que forman el capital y más moderados en la productividad durante los años de fuerte

crecimiento del output agrario europeo, es decir, hasta mediados de la década de los 80. Después, tienden hacia el patrón occidental de disminución o mantenimiento de los inputs, siendo la productividad la principal fuente de crecimiento.

El segundo capítulo analiza las diferencias en el crecimiento de la productividad del trabajo agrario, explicadas por la evolución de la productividad de la tierra y por el cociente de la tierra y el trabajo. Analiza además, la evolución de la dispersión de la productividad del trabajo, observando que esta dispersión se mantuvo o decreció levemente en la segunda mitad del siglo XX. En los modelos econométricos planteados, en el primero, se concluye que tuvo una gran importancia la ratio de tierra por trabajador en la explicación de estas diferencias. La tendencia del aumento de la tierra por trabajador en Europa vino principalmente explicado por los procesos de cambio estructural que se dieron en la segunda mitad del siglo XX. Asimismo, el papel que han jugado las causas próximas a través de la irrigación, de la maquinaria, del ganado, de los fertilizantes químicos o del capital humano ha sido también de importancia. Por último, las causas fundamentales del crecimiento económico también han sido determinantes a la hora de explicar estas diferencias, ya que pertenecer a un sistema de planificación central o a la Unión Europea tuvo una relación negativa y positiva, respectivamente, con la productividad del trabajo. Además, la geografía, principalmente la pertenencia a una determinada zona bioclimática, fue esencial para entender estas diferencias. Por otro lado, en un modelo econométrico planteado, que es un análisis dinámico, se concluye que tuvo una gran importancia el nivel inicial de la productividad del trabajo, así como de los ratios tierra y maquinaria por trabajador. De esta forma, lo que muestra el análisis es la existencia de beta convergencia hacia distintos niveles de estado estacionario, que están determinados por estas dos ratios.

Las conclusiones del tercer capítulo clarifican los determinantes de la TFP agraria en Europa. Los resultados que aporta este capítulo dejan patente la relevancia de las causas fundamentales a la hora de explicar las diferencias de la TFP agraria en Europa. La geografía influyó decisivamente en las distintas tendencias de la TFP. Más concretamente, los países nórdicos con climas con

temperaturas más frías tuvieron menores incrementos en esta variable. Por otro lado, los países mediterráneos, a pesar de su aridez, tuvieron crecimientos más fuertes, debido principalmente al efecto que tuvo la irrigación, que sumada a una mayor cantidad de horas de sol, les permitió superar este obstáculo geográfico.

Las instituciones no tuvieron un papel menor a la hora de explicar estas diferencias. Los países con mayores libertades civiles y derechos políticos tuvieron crecimientos mayores de la productividad de la agricultura. Asimismo, la apertura comercial de un país tuvo una relación positiva a la hora de explicar el crecimiento de la productividad. En cambio, la existencia de políticas de apoyo a la agricultura perjudicó a su incremento, ya que permitían el mantenimiento de recursos en explotaciones o actividades de baja productividad. Asimismo, la pertenencia a la Unión Europea también contribuyó al crecimiento de la productividad. Por último, la influencia positiva del capital humano en la TFP también es de resaltar en los resultados.

En el último capítulo, el dedicado a América Latina, se alcanzan distintas conclusiones. La primera entre ellas es que las principales fuentes de este crecimiento han sido las incorporaciones de factores productivos que forman el capital, especialmente hasta la década de los 90 durante los períodos de predominio de las políticas ISI y de la crisis de la deuda externa. Al final del siglo XX y principios del XXI, con la liberalización económica de estos países, la principal fuente de crecimiento productivo es la TFP.

Pero la búsqueda de un mismo patrón latinoamericano nos hace observar también la productividad del trabajo agrario y sus componentes: la productividad de la tierra y la tierra por trabajador. Analizando éstos podemos observar la existencia de diferentes patrones. Por un lado, estarían Argentina y Uruguay, países que en 1950 eran los más avanzados de la región, que mantenían altos niveles de productividad del trabajo, ya en el año inicial del estudio, y tienden a incrementar esta productividad, aumentando su ratio tierra por trabajador. En cambio, Colombia y Chile optaron por incrementar considerablemente su productividad del trabajo, gracias a crecimientos de su productividad de la tierra. El caso intermedio sería el venezolano, que obtuvo crecimientos similares de ambas productividades parciales. El conjunto de la región se situaría en esta

situación intermedia, destacando el caso brasileño que comenzó en esta situación intermedia, pero acabó acercándose al patrón argentino.

La investigación planteada en esta tesis no es necesariamente un punto final en la investigación de los determinantes de la productividad de la agricultura en el largo plazo. Quedan varias cuestiones por ampliar y desarrollar.

El estudio de los determinantes de la productividad de la agricultura se podría estudiar desde un punto de vista regional. Por ejemplo, el caso español puede ser interesante. España por sus características geográficas no pudo incorporar algunas innovaciones que beneficiaron al crecimiento económico en países noroccidentales europeos como la introducción de leguminosas en el siglo XIX. Las diferencias de las condiciones geográficas de unas regiones o provincias con otras son relevantes, lo cual puede clarificar el papel que ha tenido la geografía en el distinto desarrollo agrario de las regiones españolas. Los distintos obstáculos geográficos de algunas provincias se han solventado gracias a la irrigación. El impacto por tanto de esta innovación y de la geografía no ha sido igual a lo largo del territorio español, así como el impacto medioambiental que todo ello ha supuesto. Todo ello, abre una vía investigadora para conocer el impacto de esta innovación y de esta causa fundamental del crecimiento económico en la productividad y en el desarrollo agrario.

Desde el punto de vista de llevar la investigación hacia una perspectiva regional, eso además permitiría ampliar las formas de medición de las causas fundamentales del crecimiento económico como pudiera ser con variables medioambientales específicas como la temperatura, precipitaciones o las condiciones orográficas.

Por otro lado, si fuera posible obtener alguna medida de desigualdad de la renta o en la distribución de la propiedad de la tierra, también sería interesante el estudio de la incidencia de la desigualdad en la productividad de la agricultura. Es más, como el acceso a los recursos podría incentivar la productividad de la agricultura. Se trata de momento de una idea tentativa, pero que su estudio es realmente sugerente.

Esta tesis, como se ha comentado antes, es una tesis de historia económica, que estudia las grandes tendencias del sector agrario de varios países en Europa y Latinoamérica, así como los determinantes de las diferencias de la productividad de la agricultura. En varios de los capítulos que la forman se estima la TFP agraria desde la metodología del *growth accounting* para observar la tendencia de la productividad. Quizás para futuras investigaciones, sería relevante estimar este tipo de productividad con otra metodología para poder comparar las diferencias de los países, incluso calcular también los determinantes de esta nueva medición para otorgarle una mayor robustez a las estimaciones realizadas aquí.

Además, las tendencias, europea de incrementar el porcentaje de producción ganadera sobre la total y la latinoamericana que es de reducir este porcentaje, suponen cambios productivos que afectan a la productividad del sector. El estudio de los cambios en la estructura productiva de la agricultura puede ayudar a explicar no sólo los determinantes de la productividad, sino también la relación de algunas de las causas del crecimiento económico con la producción y productividades agrarias. La producción agrícola y la ganadera se ven influenciadas, al igual que la agraria total, por las distintas causas del crecimiento económico, ya sean las próximas y las fundamentales. Por ello, el estudio de la relación de estas causas con la productividad puede ser también clarificador.

El análisis de las fuentes del crecimiento de la producción y de la productividad de la agricultura puede ser interesante llevarlo a otros horizontes temporales. Uno de éstos sería el de las últimas décadas del siglo XIX y primeras del XX. Desde la década de 1870 hasta la Primera Guerra Mundial, hubo un contexto histórico y agrario muy sugerente. Los países europeos vieron como sus productos agrarios se enfrentaban a una creciente integración comercial y a una mayor competencia internacional. Varios países optaron por proteger sus productos, mientras que otros se inclinaron por cambiar su estructura productiva. En este contexto, sería muy interesante analizar las diferencias de la productividad agraria que se produjeron en este período. Tanto el progreso técnico y su diferente adopción como el potencial de mercado pudieron tener un papel relevante en la explicación de estas diferencias.